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The

American Scientific Monthly;

EDITED AND PUBLISHED

BY

PROF. GUSTAVUS HINRICHS.

FROM JULY TO DECEMBER, 1870.

IOWA CITY, IOWA:
GRIGGS, WATSON, & DAY, DAVENPORT, PRINTERS.
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1870.

AMERICAN SCIENTIFIC MONTHLY.

Edited and Published by Prof. Gustavus Hinrichs.

VOL. I. JULY, 1870. No. 1.

THE PAST AND THE PRESENT.

FOUR thousand years before the Christian era, one of the mighty of this earth erected a gigantic funeral monument for himself. It was a pyramid, one hundred and forty-six meters high, and two hundred and thirty meters each side of the base; and, in order to pile up these eleven thousand cubic meters of stones which were to perpetuate his memory, Cheops forced one hundred thousand men to work thirty years. The workmen were exchanged against others every three years.

Two great nations, friends of the arts and sciences, will soon applaud the completion of the Mont Cenis Tunnel, which has a length of three leagues (lieues), and a cross-section of forty-eight square meters. Thus, half a million of cubic meters will be taken from the natural barrier which separates those two nations, and for this work, the exertions of five hundred workmen, relieved three times a day, have been sufficient in the course of ten years.

Do not these figures speak volumes?

These are the significant words wherewith Monsieur A. Cazin closes a most interesting lecture, delivered this winter at the Sorbonne, in Paris.* We put these words at the head of our new SCIENTIFIC MONTHLY, because this striking contrast between the Past and the Present *is due to the progress of science,* and to nothing else.

Not only is the contrast a striking one in the results attained, but also in the motives which lead to the great enterprises mentioned.

In the *Past,* we have the one man compelling the masses to toil for years upon an utterly useless structure, merely to gratify the pride and vanity of the despot. In the *Present,* we see the nations break down one of the great barriers opposing their friendly intercourse, not at the command of a despot, but of their own free will and accord ; and this stupendous barrier yields not to the united efforts of hordes of slaves, which are scarcely above the level of the brute, but it literally crumbles before the breath of modern science! For, before commencing the work at all, the geologist has accurately and correctly predicted what kind of rocks would be encountered on the way through the mountain. Thereupon, the practical philosopher catches the brook running down the mountain sides, forces it to condense the air, and, finally, makes this air move the drills, before which the solid rock yields so rapidly that, in a few weeks from the present moment, the entire barrier will have crumbled down. Thus, the tunnel is literally blown through the mountain — the very Alps crumbling before the breathing of modern science.

But so, also, the Alps of ignorance, superstition, and barbarism are yielding before the gentle breath of this same progressive modern science. It has made almost the entire humanity one living being, wherein the great cities and towns are gangliae connected by telegraphic nerves, and nourished by railroad arteries and canal veins; and, as if to make up for the immense size of this organized body, the telegraphic nervous excitement is transmitted thousands of times faster than the nervous excitement in our own bodies. If telegraphic communication were only "*as quick as thought*" we should deem it exceedingly slow; for, in air lines, the telegraphic dispatch travels more than a *million* times as fast as thought, and, even through the oceanic cable, it passes some two hundred thousand times as fast as in the nerves of our body!

---

* Revue des Cours Scientifiques, 1870, p. 189.

But let us turn once more to the case presented to us by M. Cazin, merely to contrast the *power* which *modern science* enables the freed man to exert with that of the ancient slave erecting the pyramid.

A very simple reduction of the above given numbers will show that *the power of each one of the workmen, freed and directed by modern science, is equivalent to the power of thirty thousand of the slaves who reared the pyramid!*

Our "SCIENTIFIC MONTHLY" is to be an exponent of this modern science. We trust that it will find so many active friends that it may grow in *size* and *fullness*, so as to become more and more worthy of being an exponent of that spirit which is fashioning the age.

FASHIONABLE POISONS.

THE demand for "*fashionable poisons*" is decidedly on the increase in this country. The trade is, of course, ready to supply this demand, especially since the profits in this business are simply enormous. The customers who call for fashionable poisons do not want any cheap goods; for, to them, the price alone is the standard of value. The manufacturers have learned this lesson thoroughly. They supply the fashionable poisons in elegantly finished vessels, at very high prices, and often even under patriotic names;* and, considering the deplorably low state of scientific knowledge of the people, they kindly supply the deficiency of our schools by enclosing in their packages printed directions for the use of the fashionable poisons.

---

* Martha Washington's Hair Restorative. Prepared by Simonds & Co., Fitzwilliam, N. H.

In a great many cases, the retailer — usually a druggist — knows perfectly well that he is selling poisons; but the customers do call for it, and he merely supplies the demand! Besides, our philosophical temperance friends do not yet fight fashionable poisons; we know many who are steadily using these poisons themselves.

However, at times, the manufacturer is too smart for the retailer; and the latter thus may, in good faith, warrant an article as free from poision, when, in reality, it is a strong poison. We have, ourselves, detected great quantities of lead in cosmetics which had been warranted to be free from this poisonous metal.

From what precedes, it will already be understood that we refer to the various *cosmetics* as fashionable poisons. In these preparations lead is very frequently contained in large proportions. Three cases of *lead-palsy*, recently observed and described by Dr. Lewis A. Sayne, of New York city, have led to a chemical investigation of these articles by Professor C. F. Chandler, chemist to the Metropolitan Board of Health. From the official report of this eminent chemist, published in the American supplement to the May number (1870) of the *Chemical News*, we copy the following few facts and conclusions: —

In one fluid ounce of those fashionable poisons which are sold as *Hair Tonics, Restoratives*, etc., Prof. Chandler has found the following amount of *metallic lead:*

	GRAINS.
Clark's Distilled Restorative for the Hair	.11
Chevalier's Life for the Hair	1.02
Circassian Hair Rejuvenator	2.71
Ayer's Hair Vigor	2.89
Prof. Wood's Hair Restorative	3.08
Dr. O'Brien's Hair Restorer of America	3.28
Gray's Celebrated Hair Restorative	8.39

Phalon's Vitalia	4.69
Ring's Vegetable Ambrosia	5.00
Mrs. S. A. Allen's World's Hair Restorer	5.57
L. Knittel's Indian Hair Tonique	6.29
Hall's Vegetable Sicilian Hair Renewer	7.13
Dr. Tebbett's Physiological Hair Regenerator	7.44
Martha Washington's Hair Restorative	9.80
Singer's Hair Restorative	16.39

Indeed, all but one of the restoratives investigated contain *lead* as an essential constituent. The exception is Hoyt's Hiawatha Hair Restorative, which contains silver instead of lead.

The following are Prof. Chandler's final conclusions, which we recommend to all those who are in the habit of buying fashionable poisons: —

"1. The Hair Tonics, Washes, and Restoratives contain lead in considerable quantities; they owe their action to this metal, and are, consequently, highly dangerous to the health of persons using them.

"2. With the single exception of Perry's Moth and Freckle Lotion, containing corrosive sublimate, the *lotions* for the skin are free from lead and other injurious metals.

"3. The *enamels* are composed of either carbonate of lime, oxide of zinc, or carbonate of lead suspended in water. The first two classes of enamels are comparatively harmless — *as harmless as any other white dirt when plastered over the skin, to close the pores and prevent its healthy action.* On the other hand, the enamels composed of carbonate of lead are highly dangerous, and their use is very certain to produce disastrous results to those who patronize them.

"4. The white powders for the skin are harmless, except in so far as their application may interfere with the healthy action of the skin."

SOLAR ENGINES.

WE copy the following items from a recent paper of M. Cazin, 1870, Nov. 12, *Revue des cours scientifiques,* on the various natural forces used by man for the performance of mechanical work: —

"Even in the earliest ages, the important problem of converting solar heat into mechanical work had attracted the attention of several distinguished men. This question has been again raised in our own time, and to M. Mouchot, Professor in the gymnasium at Tours, has been reserved the honor of first constructing an engine operated exclusively by the sun.

"A complete history of his experiments is contained in his interesting volume entitled 'Solar Heat,' from which the following particulars are borrowed: —

* * * * * *

"'The principles on which a solar engine is constructed will be better understood by first considering a simple physical experiment.

"'Here are two concave silver mirrors, so situated that their axes coincide. A source of heat is placed in one of the foci; in the other is a small boiler, constructed according to the plan of that used by M. Mouchot. It consists of a vessel of blackened copper-plating, surrounded by glass, and containing ether.

"'The rays of light and heat proceeding from the flame in the focus of the first mirror are reflected parallel to one another; striking the second mirror, they are again reflected from its silvered surface and brought to a focus at the boiler. Passing through the glass, the heat rays are absorbed by the blackened copper, causing a rise in the temperature of the contained liquid. At the same time, however, the copper boiler is exposed to a cooling influence, inasmuch as its temperature is higher than that of surrounding objects; it is in order to diminish the loss of heat from this cause, that the copper vessel is enclosed by glass. That glass permits luminous heat rays to pass through it, but is impervious to dark heat, is a fact well known to physicists; as the heat radiated by the boiler *is* dark heat, it is evident that the glass enclosure serves to prevent its escape. By means of this artifice, the temperature of the liquid may be raised to the boiling point.

"'You see here a jet of ether-vapor coming from our miniature boiler; we might conduct it into a small cylinder containing a piston, and cause it to perform work, but will content ourselves by making the vapor visible by setting it on fire.

"'In the preceding experiment we have applied three principles:—

"'1. That the reflecting power of polished silver is higher than that of any other surface.

"'2. That lamp black has the greatest heat-absorbing capacity.

"'3. That glass, although transparent for luminous heat rays, is impervious to dark heat.'

"The application of the above principles, adopted by M. Mouchot, is the same as that in the experiment just given.

"You see here a small model, which works quite well after being exposed to the sun's rays for half an hour.

"The heating surface of the boiler is very large in proportion to the contents, consisting, as it does, of two concentric cylinders of unequal height, joined at their lower end. The upper base of the outer (higher) cylinder carries a lid, on which is placed the steam engine. The water of the boiler fills only the circular space between the two cylinders. The solar rays are concentrated by means of a concave silver-plated reflector, placed on the side of the boiler opposite the sun. In this manner, with a boiler containing six litres of water, M. Mouchot succeeded in obtaining steam of five atmospheres pressure.

"This remarkable result deserves the special attention of those engaged in industrial pursuits. In tropical countries the solar steam engine might be made of very great service.

"Now, while Europe is hurrying down to the Isthmus of Suez — to a land where the sun darts his fiercest rays, and where, for many consecutive days, the heavens remain unclouded — why should not this application of solar power receive a new impetus, again bringing the freshness of youth to those once blooming regions?

"To gain a correct conception of the motive power afforded by the sun, let us take as data, the experiments of Pouillet.

"In Paris, when the climatic conditions are most favorable, a surface of one meter square receives from the sun thirteen calories per minute. It is probable that, in the equatorial regions, where the atmosphere is clearer, as much as fifteen calories might be obtained; accordingly, a surface ten meters square would receive fifteen hundred calories per minute, or twenty-five calories per second. If this entire amount of heat could be converted into work, it would give a force of one hundred and forty-two horse powers. But a good steam engine, of average pressure, can use only sixteen per cent of the heat taken up from the surface by the water of the boiler; hence, if all the heat falling on a reflecting surface of ten meters square were absorbed by the boiler, it would perform a work of but twenty-two horse powers. A concave reflector, having a surface of four and a half square meters would, therefore, give one horse power.

"Imagine, then, an apparatus similar to the one here exhibited, one meter high, and bearing on its side a mirror of the same height, and four and a half meters breadth, its focus being in the centre of the steam boiler; you will then have a steam engine of one horse power, capable of being set in motion by the sun."

Since the first experiments of Mouchot, our American engineer Ericsson, has constructed a solar engine; his results confirm those of Mouchot. W. C. P.

SCIENCE FOR CHILDREN.

THE schoolmasters of the present day may be divided into two categories: those who *teach*, and those who *hear lessons ;* the latter class, unfortunately for the next generation, being by far the more numerous. The mischief done to the community generally by the short-comings of inefficient teachers, is too well known to every one who has pierced below the surface of the great question of middle class education. The difficulties, however, that beset a science teacher, in his endeavors to force scientific truths into the unwilling and unprepared minds of boys who have been subjected to the sway of these same lesson-hearers, can only be realized by those who have gone through the task. The case of a senior science class which has been under my charge for some months past, will illustrate my meaning most fully. It consists of about a dozen boys, whose ages range between fourteen and seventeen years, and they receive, twice a week, an hour's instruction on chemistry and physics. The class may be divided into two distinct portions by a perfectly sharp line. Four of the boys have had the advantage of six or seven years' training under the principal of the school, who is not only a ripe scholar, but also an efficient teacher,—a very rare collocation in these days. The rest have simply learned lessons all their lives. The four boys who have been *taught*, are as mentally distinct from the others as if they were different species of the same genus. The first four are bright, attentive, wide-awake (I know of no other term to express exactly what I mean), logical, and clear-headed; they can fairly follow a chain of scientific reasoning, and reproduce it afterwards link by link; they have a certain power of induction and deduction, although, of course, being new to science, this power is, necessarily, only just awakened; they can collect and correlate facts and ideas; they can enumerate a series of phenomena in logical sequence; in a word, although their industry and application are far from colossal, the task of teaching them the truths of natural science is a comparatively easy one.

The other boys, as I have said before, almost form a distinct mental species. They cannot understand the possibility of learning anything without the aid of a book, and the idea of finding out anything for themselves has never entered their heads. Still, they are far from stupid boys, being all possessed of good average brains; yet, their faculties have not merely been allowed to remain undeveloped, but they have been utterly entangled, stunted, and stultified by what Dr. Frankland would call their "previous school contamination." These boys, it must be understood, are the sons of parents belonging to the upper stratum of the middle class, and have, mostly, been to schools conducted by university men, with honorable initials appended to their names — men, in fact, who are scholars, but, emphatically, no teachers. Their great fault is a total want of mental method, without which the greatest brain is as naught. They are at home in Virgil and Horace; some of them are fair Greek scholars; they have "been through" Euclid, and can work moderately difficult algebraical problems in a certain mechanical fashion; they are well acquainted with the leading facts in English history, and know the exact position and population of Adrianople; but, as far as real mental power goes, any poor boy who has been in a national school for three years, would beat them hollow.

These facts surely point out the absolute necessity of beginning scientific training at a very early age, and, I fancy, this necessity has not been sufficiently dwelt upon in the numberless essays, letters, lectures, and evidence on the subject of scientific education with which we have been deluged during the past decade. There seems to have been a notion abroad, that scientific teaching should not be begun before the age of twelve or fourteen; but why, I would ask, should boys' minds be allowed to remain fallow during all these years? The minds of boys of seven and eight should, surely, be as carefully developed as those of their seniors, and there is, certainly, no means of pure mental culture so successful as scientific teaching. A boy of this age should not be taught science so much for the sake of acquiring a certain number of facts, as of developing his powers of observation and reasoning, and giving a proper tone to his mental faculties. A boy of eight or nine takes a morning canter of three or four miles on his pony, not for the purpose of getting over some seven thousand yards of ground, but to strengthen his muscles and improve his carriage. His science lesson should be an intellectual canter, taken with a view to strengthening and improving his mental muscles and carriage.

In National and British schools, and in some few middle class schools, conducted on rational principles, this great want is supplied by what are known as "Object Lessons." A natural object, such as a piece of lead or sugar, is placed before the class, and its physical properties are described by the pupils, with the aid of questions from the teacher. Its origin and manufacture are also given in the case of older children, and the whole is noted down on black-board in as condensed a manner as possible; the lesson being reproduced in a miniature form, either *viva voce*, or in writing. These lessons are most excellent in their way, but, as generally taught, they are too desultory and unsystematic to effect fully their intended purpose. The principal manuals on the subject show a want of arrangement and system that greatly detracts from their value. One day the children are supposed to learn a lesson on a piece of iron; the next on a flower; the third, on a shell; and so on. Too much stress is laid upon cultivating the powers of observation, and too little on connecting the facts observed and drawing conclusions from them. The lesons, too, are very frequently unconnected with each other, and the facts taught lean almost too much towards the practical and economic side of knowledge, and too little to that of systematic science. Great scientific ignorance is displayed in many cases; for instance, one book informs us that plumbago is an ore of iron; that iron is generally found as an oxide, in combination with *sulphuric* and carbonic acid; that fluor spar is composed of fluoric acid and lime; and that lime unites with various proportions of carbonic acid. These mistakes are the result of imperfect scientific knowledge, and may be passed over for the sake of the valuable instruction given to teachers, which cannot fail to produce most excellent results, if applied to systematic scientific teaching.

It may be urged that children of eight or nine are too young for systematic science-teaching, but facts prove the contrary. An ordinarily intelligent boy or girl of this age is perfectly capable of understanding the broad differences between the animal, vegetable, and mineral kingdoms; that there are more gases than one in the world; that some of them are colorless, while others are brown, or green; that some burn, and others do not; that some plants grow from the inside, while others grow from the outside; that some animals have jointed backbones, that others have their bones outside their bodies, while others have none at all. Facts such as these are perefectly comprehensible to children even younger than those I have named. During the first two years of a child's school life, after he has learned to read and write, he should be carried through the whole range of physical science in a systematic manner. The fundamental truths of chemistry and physics should be first taught him, all theoretical considerations being left aside. As few definitions as possible should be given, the whole task of the teacher at the commencement being to cultivate the powers of observation to the utmost. Gradually, the powers of induction over deduction may be developed; facts and phenomena should be compared, and conclusions drawn from them. Order in thought and description should be specially insisted upon, and occasional re-teachings of the ground already gone over should take place. The objects of this preliminary science-teaching should be two-fold: first, and foremost, to train the mind and form the judgment; and, secondly, to give the child a general idea of the object and scope of the natural sciences. At the age mentioned, the faculties are all fresh, and in full process of development, and such is the desire to exercise them in intelligent children, that their thoughts often run wild. There is nothing a child likes so much as investigation, or "finding out all about things," as he himself would phrase it. The boy in the nursery rhyme, who cut the bellows open to see where the wind came from, is a type of his class. Unfortunately, at the present time, scientific teachers for children are extremely rare; but let the want once arise, and the demand will soon be met. We have plenty of scientific teachers and lecturers for boys and men, but the child has hitherto been left out of consideration. Teachers, in the true sense of the word, are every day on the increase, and even the old-fashioned schoolmasters are beginning to see very plainly that they must alter their system of instruction and yield to the pressure of the times. But it is not only upon these that I would urge the necessity of beginning science teaching at the earliest possible period, but, also, upon those who have already adopted science as part of the ordinary school curriculum for the older boys.

CHARLES W. QUIN.

From "*Nature*," Dec. 23, 1869.

PRACTICAL IMPORTANCE OF EXPERIMENTAL RESEARCH.

EXPERIMENTAL scientific research, in the stricter sense of the word, is a comparatively modern thing, and, though it has existed in a more limited degree during many centuries, it can only freely exist and thrive in civilized countries. Even at the present time, in consequence of the peculiar nature of the occupation, its hopelessness as a source of emolument to the investigator, the great skill and extreme self-denial required, and, frequently, danger incurred in its pursuit, and the consequent great difficulty of achieving success in it, *scarcely one person in one million of the population of*

England is exclusively devoted to it, although a much greater proportion occupy a small amount of their time in its advancement.

The extension of physical and chemical knowledge by means of experiments and observations is a national work; it benefits the nation, but does not pay the investigator. The various scientific men who discovered the chief facts and principles of science upon which steam engines, electric telegraps, and all the modern applications of science are based, received no remuneration for their researches. The results of purely scientific investigations are, generally, unsalable; because, instead of benefitting a single manufacturer only, they benefit the whole nation; the nation, therefore, being the gainer, should pay and provide for those who make such researches. And, when we consider that in this country upwards of five hundred and seventy-six millions of pounds have been expended in the construction of railways alone, and immense sums upon electric telegraphs, which would never have been expended except for such labors, and nearly all of which have given employment to numberless workmen, it is evident that the magnitude and national character of the results would fully justify national encouragement of original experimental research.

The more abstract an experimental investigation is, the more important and widely diffused are its practical results. Who would have thought, when *Oersted*, in his original abstract research in electro-magnetism, first made a magnetized needle move by the influence of an electric current, that his labors would lead to the expenditure of many millions of pounds in the laying of telegraphs all over the earth, and the employment of many thousands of persons in their construction, maintenance, and use? And who can tell how many similar important discoveries have been lost to the nation, and how much of the present deficiency of employment for workmen has arisen, in consequence of experimental scientific investigators not having been paid for their labors?

At present, original experimental researches are generally made by teachers of science, who expend a portion of their in-comes in making experiments and observations; but the very limited means of such men is a serious loss to the nation, by greatly retarding the progress of discovery, and, consequently, also of improvements in manufactures. Many of the experiments, also, necessary for the development of new discoveries, are beyond the means of such persons at present, and cannot be made without the command of greater wealth.

If England is to keep pace with the progress of foreign manufacture, and keep her workmen fully employed, there must not only be a general diffusion of scientific knowledge throughout this country, but there must also be a national encouragement of original scientific investigation.

Has it been wise in our governments thus to overlook a great source of the nation's wealth, to disregard a most important means of national economy, to neglect the great fountain-head of industry? Shall we allow foreigners to supplant us in manufactures, and shall our fellow men continue to be driven to emigration by want of employment, or shall we develop for them new sources of labor by means of original experimental research? It needs only to bring the subject fairly and effectually before the attention of our present enlightened and progressive government, to secure its careful and early consideration.

From "*Nature*," No. 25. GEORGE GORE.

EARTHQUAKES AND VOLCANIC ERUPTIONS OF 1869.

MORE than a hundred earthquakes are recorded as having occurred in different parts of the globe during the year 1869. Most of these consisted of single shocks, but many of them were prolonged over weeks, and even months.

In these *continuous* earthquakes the shocks followed each other sometimes in rapid succession, sometimes more slowly. For example, at Ragusa, in Dalmatia, where an earthquake continued throughout the entire first half of the year, fifty-three shocks were counted in the course of four weeks (in May). Even the well known earthquakes which disturbed the countries bordering on the middle Rhine during the winter months of the past year were, notwithstanding their comparative feebleness, characterized by a great number of separate shocks. At the town of Groszgerau, over six hundred had been perceived up to the end of the year. The extent of territory over which these shocks were felt was by no means small, at least, in the case of the severer ones. In many instances, earthquake shocks very distinctly felt in Groszgerau, were also observed in Marburg, on the one side, and in Stuttgart and Saarbrücken, on the other. The more violent earthquakes of the past year were distributed among one hundred and thirty different days. It should be remembered, however, that many were of long duration, consisting, besides the stronger shocks, of a great number of feebler ones. We should recollect, also, that there are regions, such as Panama, and the groups of islands south-east of Asia, where earthquakes occur almost daily, only the severer ones receiving any special mention. Bearing these facts in mind, it becomes probable that not a day passes of the whole year, perhaps not an hour, without the occurrence of an earthquake shock somewhere. Among such a multitude of shocks, it will be readily comprehended that, in many cases, shocks were felt in different, often widely separated, countries on the same day. This was the case on the following days of the year 1869 :—

January	10,	in	Siebenbürgen	and	East Indies.
March	1,	"	Steiermark	"	Athens.
April	1,	"	Bucharest	"	Caucasus.
"	18,	"	Constantinople	"	Symi.
June	6,	"	Chemnitz	"	New Zealand.
July	23,	"	Guyaquil	"	Visp (Switz).
August	21,	"	Peru	"	Caucasus.
October	2,	"	Cormons	"	Rheinthal.
Nov.	12,	"	Groszgerau	"	Bacska (Hun).
"	25,	"	Innsbruck	"	Mayence.
"	26,	"	Altdorf	"	Mayence.

Dec.	18,	"	Mayence	"	Hildesheim.
"	27,	"	Darmstadt	"	California.
"	28,	"	Groszgerau	"	Corfu.

These earthquakes were distributed with considerable uniformity among the different seasons and months of the year. The maximum number occurred during the spring (27); the minimum, during the autumn (22).

Eleven volcanic eruptions were recorded during this year. Of European volcanoes, only Ætna is here included, and its activity was of only a few hours duration. Only among the less known volcanoes of Southern and Central America — Puraci in Columbia, Cotopaxi, Pinchinca, Misti, etc. — were there any violent eruptions.

Santorin,— celebrated on account of the volcanic formation of several new islands during the year 1866,— is not yet extinguished; its eruptive activity, however, seems to be now on the wane.—*Der Naturforscher*, 1870, *p.* 135.

PROGRESS IN THE NEST ARCHITECTURE OF SWALLOWS.

BY A. POUCHET.

IT is evident that the habits of animals, very far from being stable, have rather been undergoing continued changes during the different phases of the earth's history, and that, with many of them, these habits are no longer the same they were a few centuries ago. In their methods of building, some of them are, even at present, carrying forward very considerable improvements.

"One of the most interesting portions of the history of birds," says Spallanzani, in one of his important monographs on the swallow, "is that which relates to the form and structure of their nests. Each species builds its nest according to a model peculiar to itself, which it never changes, and which is perpetuated from century to century."

Although this opinion is shared by many naturalists, it is, nevertheless, a manifest error, which, on closer examination, we cannot fail to recognize as such. It certainly will not be found that species which, seeking shade and solitude, hollow out for themselves habitations in the earth, will bring up their families in the tops of trees, or within our houses; we shall find, however, that in the lapse of years, each species learns to adapt its habitation to external circumstances.

Certain birds which at present make use of the products of our factories in the construction of their nests, must, necessarily, have used other materials before those factories were erected. The European yellow thrush, for example, now sews its nest to the boughs of trees by means of strings and bits of thread. It must have used some other expedient before the industry of man afforded it these products.

We know that for several centuries past, the house-swallows (Hirundo urbica) have made themselves quite at home in the midst of our populous cities. From year to year these little masons build their nests around the gothic windows of our churches, or beneath the eaves of our dwellings. Their habitations are constructed upon ours. The chimney-swallow, still more familiar and audacious, frequently installs itself within the interior of our dwellings, and even in our factories, without seeming at all frightened, either by the noise of the machinery, the fires of the furnaces, or the movements of the workmen. Assuredly, the habits of these birds are very different to-day from what they were at an earlier period.

During the pre-historic ages, when man led a wild life, roving unclad through the forests, and possessing no permanent habitation, the swallows must have built their nests in places quite different from those in which they build them now. Neither were they domesticated, at a later date, either within the lacustrine villages, or upon the megalithic monuments of our ancestors; these dwellings affording them no security, no suitable protection against the weather. Then, all built their nests among the rocks; now, only a part of them select such localities. The same may be said of the storks, which, at present, build their nests on roofs and chimneys in the midst of populous cities. With the progress of civilization, these birds, too, have effected considerable changes in the modes of constructing their nests. They have preferred to exchange their primitive, less commodious dwellings, for those which have been offered them by man. Such changes in the occupations and habits of birds ensue, perhaps, much more rapidly than is generally assumed.

Observations on the modes in which house-swallows build their nests, have served to convince me that these birds have made marked improvements in this respect withing the first half of the present century. While examining the nests of these swallows brought to me that I might make drawings of them, I have been surprised to see that they were not at all the same as those I had collected at an earlier date. A very careful comparison with nests I had myself collected forty years ago, and with still older drawings, has convinced me that the bird-architects of to-day have very essentially changed the modes of building in vogue with their fathers, and that a great architectonic revolution — a real improvement in the work of their species — is in progress at the present time.

In order to study the extent of this revolution, I have investigated monuments and inaccessible rocks, by the aid of a pocket telescope. Among the nests which line the arcades of our church portals, I have seen many which exhibited the old structure; whether these were ancient constructions, merely refitted by their occupants, or whether they have been built in recent times by the still surviving architects of an earlier period, I shall not attempt to decide. Again, in other places, nests of the modern form have been found intermingled with those of the old construction. On the other hand, in the newly built streets of Rouen, the swallows have, everywhere, built after the new model. * *

Among ornithologists who have carefully described the nest of the house-swallow, Montbeillard and Vieillot have given the most faithful picture of their ancient configuration. The nest, say they, constitutes the fourth part of a hollow hemisphere, fitting, by its sections, to the recesses of the window or monument in which it is built, and having a very small round opening. To be precise, it should be stated that these nests represent, in their breadth, two-thirds of this spherical section, and that they have an entrance on the upper side, consisting of a small round hole from two to three centimeters in diameter, and barely admitting the body of the bird. The modern nests, on the contrary, represent the fourth part of a hollow semi-ellipsoid, having very elongated poles, and with its three sections attached to the walls of the edifice, except that part of the upper section on which the entrance is placed. This entrance to the new nest is not a simple round hole, as in the old construction, but a very elongated transverse slit, its lower side being formed by a segment cut from the margin of this upper section, and bounded above by the wall to which the nest is fastened. The ends of this opening are rounded; it is from nine to ten centimeters in length, and not more than two centimeters in breadth. These nests are much compressed vertically, and look exactly like the section of an antique drinking vase fastened to the wall, and having its edge scooped out in order to form an entrance.

There is, then, a fundamental difference between these two kinds of nests, both in their general form, and, especially, in the plan of the entrance. The new mode of construction which the house-swallow has adopted, is, assuredly, an improvement on the old. The floor of the nest presents a larger space for the movements of the family, so that the young are not so much crowded upon each other. The long opening is also better adapted to allow the young swallows to stretch out their heads, either to breathe the pure air or acquaint themselves with the external world; it serves as a balcony, so ample that two young swallows are often seen enjoying it at the same time, their presence not interfering in the least with the ingress and egress of the parent birds. These advantages could not be enjoyed in a nest where the entrance was merely a small circular opening. It is, indeed, a very narrow entrance that the parent birds have reserved for themselves in the present construction, and, on arriving before their dwelling, they may be seen clambering over its walls and making their way with considerable difficulty to its interior. For the young, however, this nest affords the most complete protection against the rain, the cold, and external enemies.— *Comptes Rendus*, 1870, *T.* 70, *p.* 492–496.

STATE GEOLOGICAL SURVEY OF IOWA.

BY C. A. WHITE.

THIS work, after being in progress under my direction for nearly four years, is now suspended, in consequence of the failure on the part of the last Legislature to provide funds for its continuance. A report, embracing the results of investigations for the years 1866, 1867, 1868, and 1869, was presented to the last Legislature, and they ordered the publication of three thousand copies of it, appropriating therefor eighteen thousand dollars. The manuscript and drawings of this report are now in the hands of Mess. Mills & Co., state printers, at Des Moines, who have already commenced the work in a very creditable manner, and it is expected that it will be ready for distribution some time next autumn.

The former geological work of Iowa, under the direction of Prof. James Hall, of Albany, New York, was confined to the eastern half of the state alone, and even the work of that half was not completed. My plan embraced the completion of the work upon the strati-graphical geology of the whole state, to be followed by the detailed examination of the whole by counties. This would have resulted in a clear understanding, not only of our mineral and other material resources, but a full illustration and description of the geological structure of the state, and its relations with that of those states which adjoin it. Fearing, from the first, that the work would be suspended before it could be completed upon such a plan, I devoted the first years of the work almost entirely to the elucidation of the structural geology, especially of the western half of the state. Several corrections have also been made of the boundaries formerly given to the surface areas occupied by several of the groups of strata, and a geological map prepared, showing the outlines of the formations of the whole state, so far as it has been possible to ascertain them. Three general sections across the state in different directions have also been prepared to accompany the map. These will be published with the report, and, besides them, the following illustrations: One hundred wood cut diagrams, to illustrate certain subjects in detail; about a dozen lithograph plates of geological sections; thirteen full-page views of different points in the state; a map of the gypsum region of Fort Dodge; a geological map-model, to illustrate, at a glance, the relative position of the different formations of the state, and a lithograph sheet showing the elevations of the surface of the state, by five profiles across it from east to west.

The report is to be bound in two royal octavo volumes of, probably, about four hundred pages each. It is divided into four parts; as follows:—

Part I. Physical Geography, and Surface Geology.
Part II. General Geology.
Part III. County and Regional Geology.
Part IV. Chemistry, Lithology, and Mineralogy.

Although the part devoted to County and Regional Geology is greater than either of the others, as the report is now prepared, the detailed work of that character is in a more imperfect stage of progress than that of which either of the other parts treats. This was necessarily so, since details of that kind must, necessarily, follow work of a more general character. Much especial labor has been devoted to the coal-field of Iowa, and many facts of the utmost importance have been clearly ascertained, but it is a matter of great regret that the productive coal measures could not have received that minute and detailed examination that their importance requires, before the survey was suspended.

No provision was made by the Legislature for the general distribution of the report, beyond about a thousand copies to public and scientific men, colleges, learned societies, &c. The remainder, about, two thousand copies, are to be placed in the hands of the Secretary of state, to be disposed of as the Census Board may direct.

The work is to be stereotyped by Mills & Co., who own the copyright, and they will, no doubt, keep a supply on hand for sale. This latter fact is mentioned, in reply of frequent inquiries as to how copies may be obtained when published.

SCIENTIFIC INSTRUCTION AT THE IOWA STATE UNIVERSITY.

THE faculty of the State University of Iowa have, with marked unanimity, resolved to recommend to the Board of Regents a new course of study for the first three years, in order to adapt the internal organization of the institution to the spirit of the new organic law passed by the late General Assembly.

According to this plan, the students have four regular hours of work, lecture, or recitation each school day. This time is equally divided between the *letters* (language, history, etc.), and the *sciences* (mathematics, physical and natural science). The dirction of these two classes of studies is to be respectively under the faculty of letters and the faculty of science, each to have complete control over *one-half* of the students' time.

Of the two hours spent in the different sciences, one hour is devoted to mathematics, the other, in the first two years, to physical, in the third year, to natural science. This order might, perhaps, with advantage to the student, be changed so as to have the second year in physical science succeed instead of precede the year in natural science; the student would thereby profit from his greater proficiency in mathematics.

After having completed this three-years course — which is the same for all students in the sciences, but permits the student, under certain wholesome restrictions, to substitute the different languages one for the other — the student can intelligently decide whether he desires to graduate in the sciences, the letters, or in pedagogics. In the last case, he needs not to have studied any foreign language, but will have spent a a great amount of time in the study of his vernacular and its literature; he may then enter the Normal Department, and, at the close of one year, receive the degree of B. D. (Bachelor of Didactics). If, however, he has studied foreign languages, especially Latin and German, he can, after two years of studies, selected according to his own pleasure from among the higher branches taught at the University, obtain either the degree of B. Ph. (Bachelor of Philosophy), or B. A. (Bachelor of Arts). To obtain the former, at least two-thirds of the studies selected by him must have been in the department of science, while, to obtain the latter degree, the same fraction should have been studied in the department of letters.

Facilities for part-graduate courses are also offered, and have, indeed, already been improved by several gentlemen in the past year. We abstain from giving forth details concerning this plan until the Board of Regents shall have taken action thereon. We believe, however, that this plan, in a judicious manner, combines the best features of the American College-System with the German University-System. It will equally prevent one-sidedness and class-drudgery; while securing familiarity with the *elements* of the principal branches of human culture, it will, at the same time, not only permit each mind to follow its own bend, but also give every individual a fair chance to correctly ascertain in what direction his mind leads him.

This new organization is especially important to those interested in science. Hitherto, most students commenced the study of science after having spent several years in book studies, especially, the dead languages. It seemed they had been imbued with the absurd notion that such studies form a proper preparation for the study of physical and natural science. Experience has, however, abundantly confirmed the common sense view, that the exclusive pursuit of such literary branches by permitting the faculties of observation and logical reasoning to slumber, does unfit students for the successful study of nature. For the sake of the student, we are glad that this system has, at last, been thoroughly abandoned. The student will hereafter commence the study of physical science immediately upon entering the University, and, in regular succession, become familiar with the elements and principles of the same. They will take up the natural sciences only after they have become familiar with the elements of physical science. Hereby the professors of physical and natural sciences will, at last, have an opportunity given to teach science in such a manner and at such a time as they deem necessary. We are glad to state that this great reform has the cordial support of each member of the faculty.

AUGUST WILHELM HOFMANN AND THE HOFMANN FEIER, BERLIN, JANUARY 8, 1870.

IN the front rank of the active chemists of the present stands the director of the magnificent chemical labratory of the University of Berlin, Professor A. W. Hofmann.

Hofmann was born April 8, 1818, in *Giessen*, Hessia, the place so famous in the annals of chemistry through *Liebig's*

Laboratory. Here Hofmann was initiated to the science whose boundaries he has been constantly widening ever since. First, he served as assistant to *Liebig*. From 1845 to 1848 he was Professor extraordinarius of Chemistry at the University of Bonn. Prince Albert was instrumental in calling Hofmann to London, where he founded the *College of Chemistry* with the means furnished him by a few wealthy friends. This institution was the first school of chemistry in England, and has long ago been made a state institution. He soon attained to high positions in London, and, although a foreigner, he was appointed Assayer of the Mint. His *Introduction to Modern Chemistry*, first delivered as a course of lectures to the pupils of the Royal College of Chemistry, in London, is universally studied by all who, after having learned the rudiments of chemical facts, desire to become familiar with the outlines of the *science* termed modern chemistry. This book is a gem, both in regard to the exquisite elegance of its mostly original experimental demonstrations of the fundamental principles of the science, and in regard to the philosophical and didactic arrangement of the principles deduced. It ought to be as carefully studied by the student in abstract philosophy as it *is* studied by all true students in physical science. The fourth German edition* of this masterly treatise of a branch of inductive philosophy was published in 1869.

In 1865, Hofmann definitely accepted the call from the University of Berlin. Here he erected an immense and costly chemical labratory in the very heart of Berlin, the ground alone costing some two hundred thousand dollars. He also founded the *German Chemical Society* at Berlin. At the termination of his presidency of the society,—an office which he declined to accept the third time,—a grand banquet and festival was given him by this society, on the 8th of January, 1870. From the *report* on this "*Hofmann Feier*," published in an appendix to number three of the "Berichte," we translate some of the most characteristic words* of the speech of Professor Magnus, who presided at the festival. We hope, at some other time, to give a description of the chemical palace erected by Hofmann, especially if the circulation of the SCIENTIFIC MONTHLY should warrant the insertion of the necessary plates. Professor G. Magnus spoke as follows: —

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* I take this opportunity to thank the author for sending me a copy of this beautiful work.—Ed.

"It was in the fall of 1863 when Prof. Hofmann * * came to Berlin, in order from here to visit the different chemical laboratories of Germany. He had undertaken to build a grand laboratory in Bonn. * * *

"Only a few months after, Mitscherlich succumbed to a painful sickness, and now the difficulty arose to find a successor to so eminent a man. All eyes turned immediately towards Hofmann, * * * but few could believe that he would exchange his brilliant position in London against the simple professorship in a German high school.† Notwithstanding, we find our friend, after scarcely a year had elapsed, in Berlin. * * *

"But, gentlemen, although we thus have the *fait accompli* before us, there are many who, even to-day, shake their heads as if standing before an unsolved riddle; and, if you consider the position which Hofmann occupied in London, the solution of this riddle does, indeed, appear to be difficult. * * Besides, he could not be in doubt concerning the extent of the labors which did await him in his new position; he knew how much time and energy the erection of a great laboratory, such as our University needed, would demand. * * What can have induced him to such an exchange? Not patriotism; for, to Hofmann, England has become a second fatherland. * *

"But in no field have the differences in character, habits, and customs in action and thought between Englishmen and Germans become so apparent and striking as in the field of *public instruction.* The Englishman — and, as the individual man, so the entire nation — always pursues his aim steadily without looking aside. It is especially this steady adhesion to the chosen path that has made the nation great. But this feature in the English character also induces the youth of that country to study rapidly, and immediately to apply the acquired knowledge in business. How entirely different from this are our young German academicians (students), who nearly all come with a mature preliminary education to the University. * * With them a higher, a more ideal view of existence is dominant. It is to this circumstance that the German University-professor owes the privileged position which he occupies; that his auditors are animated with the endeavor to not only acquire the doctrine taught, but also to thoroughly penetrate the same. Such disciples can be led by the teacher to the extreme boundaries of science; in such pupils he can kindle enthusiasm for the further development of this science. * * *

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* Especially those which relate to the University work in Germany, or to Hofmann's life.

† The descriptive German name applied to the great German universities.

"A German professor, himself animated with sacred ardor for his science, cannot satisfy himself except before such students. For such students our friend felt a deep longing; and this longing it is that has brought him back again to Germany. * * *

"This desire for an intimate spiritual connection with his auditors is to be estimated the more highly in Hofmann, because he has been called the man of practical applications. Indeed, but few chemists have had the good fortune to see their scientific labors so immediately and so completely applied for the purposes of society. But our friend has, nevertheless, remained faithful to his purely scientific work; if he reaped the rich harvest of practical results, which he passed close by on his way, * * it was because they promised him new materials for further investigation, new acquisitions to theory.

"The labors of our friend demonstrate, indeed, how great an advantage industry can gain from purely scientific, and even abstract researches. The aniline-color manufactory is a daughter of theoretical chemistry. The researches wherewith Hofmann entered into science were of a purely speculative character. * * His studies on the aggregation of the elements have produced numberless compounds, of which one always evolved from the other, until these studies finally culminated in the discovery of those wonderful colors, which surround the name of our friend like a luminous wreath. But more radiant than the glory of these colors is the gain which science has reaped from these researches.

"Revolutions like those which chemistry has experienced during the past quarter of a century are not perfected at one blow, nor are they effected by any one man. * * But, although Laurent and Gerhardt were those who laid the foundation to the new structure, and although many others have taken part in the great work, still, everybody will have to admit that the labors of Hofmann, and especially his researches on aniline and its derivatives, have exerted a decisive influence on the development of ideas in modern chemistry. Let us, therefore, bring this toast to the well-being of our noble friend, whom the desire for activity in a German university has brought back into his fatherland: —

"May he be pleased amongst us; may he here find the field for his untiring scientific research; and may he succeed to implant his sacred ardor for science into his disciples!

"Er lebe hoch!"

This toast was succeeded by another, on Hofmann, by the president of the chemical society, Prof. Rammelsberg. Thereupon Prof. Hofmann replied, giving many interesting facts relative to his twenty years' stay in England, and openly acknowledging that *the desire to have pupils able and willing to understand his work* had, indeed, brought him back from lucrative positions in London to "Germany, which, more than any other country, is the fatherland of science."

Among the many high officials of the government present at the festival, he mentions our United States embassador, Mr. Bancroft, as "my dear friend, the representative of a great and free people from beyond the sea, who, by his actions among us, has renewed the consciousness of our relationship to the transatlantic brethren."

Many other speeches were made, many telegrams read from chemical societies in France, Italy, and different parts of Germany, also, mention made of special letters written to the committee from all parts of the civilized world.

Finally, a large carton, sketched by Dr. A. Bannon, exhibiting Hofmann among the results of his discoveries, was exhibited and explained. A fine photograph of this picture accompanies the description of the festival.

On the whole, the Hofmann Festival was unique, scientific, cosmopolitan, and one of those tokens which show that in Europe, at least, science has begun to reign. *Vivat, floreat, crescat!*

LIFE OF GALILEO.

THE private *Life of Galileo,* compiled principally from his correspondence and that of his eldest daughter, *Sister Maria Celeste,* nun, in the Convent of St. Matthew, in Arcetri, London. Macmillan & Co., 1870; XII. 300 pp. small, 8vo, with portrait of Galileo.

This excellent work is, evidently, due to a man thoroughly familiar with the life of *Galileo, the true father of modern science,* the great and noble discoverer of a new heaven. Hitherto, the *history of modern science* has not been written by any of its own disciples. Various metaphysicians have published works under this title, but since they were almost totally unacquainted with the methods of modern science, we need not wonder that they consider Bacon, of Verulam, as the founder of this science. It can, however, be proved that this same Bacon had not the faintest idea of those methods of the science which have led to the greatest results, and which are the most characteristic. Unfortunately, this grave error has, through the ignorance of book makers, crept into most of the elementary compilations used in the schools.

The English public has been particularly unfortunate in this regard, for the only more widely circulated work on

Galileo in the English language is that wretched web of hypocritical abuse of the grand master of modern science, offered by a man who did not even know the title of the principal work of Galileo. We refer to the life of Galileo given in *Brewster's* "Martyrs of Science" — a title which at once characterizes the spirit of that book.

The biography now before us is, on the contrary, precisely what the author states in his preface: "a plain, ungarbled statement of facts," because he has allowed "Galileo, his friends, *and his judges* to speak for themselves," by giving correct translations of all the more important documents bearing upon the private life of the venerable sage, who was slowly and deliberately tortured to death by an ignorant priestcraft.

We hope, from time to time, to give short extracts from the interesting documents and letters contained in this volume. For the present, it may be sufficient to have recommended it most strenuously to all those who would like to become familiar with the life of Galileo. G. H.

LITERARY NOTICES.

The editor takes great pleasure in recommending the following journals of popular science and of education: —

Nature.— A weekly illustrated journal of science. J. Norman Lockyer, editor; Macmillan & Co., London, publishers. Branch house, 63 Bleeker street, New York. Subscription, $5 a year. Cannot be too highly recommended.

Erganzungsblatter zur Kenntniss der Gegenwart.— Two numbers (64 pages, octavo, close print) a month, usually with illustrations, maps, and plates. An excellent journal, noticing everything of general importance in history, literature, art, geography, natural science, physics, chemistry, botany, zoölogy, mineralogy, agriculture, national economy, etc.

The Chemical News.— A journal of physical science, with an American supplement. This large quarto monthly, the best chemical journal in the English language, is published in London (W. Crookes, editor), and reprinted, with authority, by W. A. Townsend & Adams, 434 Broome street, New York, who receive subscriptions ($5 a year). The American supplement is edited by Prof. C. F. Chandler, of Columbia College, New York.

The Engineering and Mining Journal.— Rossiter W. Raymond, editor; Western & Co., 37 Park Row, publishers; $4 a year. Large, folio, illustrated weekly. The best mining journal in the world. Full reports from our western mining regions; new smelting processes, furnaces, etc.; also, papers on chemistry, mineralogy.

Scientific American.— A weekly journal of practical information, art, science, mechanics, and manufactures. Munn & Co., 37 Park Row, New York; $3 a year. Large, folio, fully illustrated. The best paper for the practical mechanic, and for every one who takes an interest in the progress of the mechanical arts.

Der Naturforscher.— Wochenblatt zur Verbreitung der Fortschritte in den Naturwissenschaften. Herausgegeben von Dr. Wilhelm Sklarek, Berlin. Very thorough summary of scientific progress. High quarto, sixteen pages, double-column, weekly.

The American Naturalist.— A popular illustrated magazine of natural history. Salem, Mass.; Peabody Academy of Sciences. A monthly, 64 pp. octavo; very excellent in contents and form. Subscription, $4 a year.

The University Reporter.— Conducted by the students of the Iowa State University. Two numbers a year, large quarto, sixteen pages, three columns. Especially useful as a local organ and for the interests of the University.

Foreign books and periodicals may be ordered from B. Westermann & Co., 471 Broadway, New York.

THE
American Scientific Monthly,

EDITED AND PUBLISHED BY

PROF. GUSTAVUS HINRICHS.

AUGUST, 1870.

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IOWA CITY, IOWA:
GRIGGS, WATSON & DAY, DAVENPORT, PRINTERS.
1870.

TO OUR READERS.

We gratefully acknowledge the very cordial welcome which has greeted the AMERICAN SCIENTIFIC MONTHLY. We have already subscribers as far west as Wyoming, as far east as Massachusetts, and as far south as Mississippi; and we have an encouraging circulation at home. But we need *many more subscribers*, and, therefore, urgently request every one of our friends to get up at least *one club* of six additional subscribers. The size of the journal will, next New Year, be determined by the number of subscribers which it has secured.

We also most heartily thank the many brethren of the political press of the west, and especially, of Iowa, for the encouraging expressions of welcome wherewith they have received the first number of our MONTHLY. We shall most earnestly strive for their continued good will and cordial support, and hope that they will often be induced to transfer articles of our MONTHLY to their columns. We would call their especial attention to those articles which relate to science instruction in schools.

AMERICAN

SCIENTIFIC MONTHLY.

Edited and Published by Prof. Gustavus Hinrichs.

Vol. I. AUGUST, 1870. No. 2.

LET US HAVE PEACE.

CERTAIN popular scientific journals seem to take a special delight in ridiculing members of the clergy, because of occasional erroneous statements made by some of the latter. Thus we find, in the June number of the Boston *Journal of Chemistry* — a paper which has a very large circulation — the following: —

"A reverend writer, who, like the Bishop of Western New York, writes D. D. after his name, has been enlightening the patrons of a Presbyterian journal out west on the developments of modern science. Among the *dicta* he lays down, we notice the following: 'No simple substance exists in nature.' It has been generally accepted as a fact, that many of the chemical elements — which are 'simple substances,' so far as our present knowledge goes — are found uncombined in nature; but since, according to our philosophic divine, 'true science is founded on *faith*' (not, of course, on *sight*), we must assume that chemists have erred in trusting the evidence of their eyes on this point.

"Again, this reverend gentleman tells us that recent geologists have demonstrated that 'granite never was a metal,' etc. He intimates that the contrary view has been an accepted 'geological dogma,' but we have never happened to meet with it. The worthy doctor is right, however, in rejecting it. The non-metallic character of granite may be considered as settled beyond a doubt."

In the July number of the same journal, reference to the above is made in the following words, after a short quotation from the *New Jerusalem Messenger*: —

"In our last number we alluded to the 'scientific' lucubrations of a western doctor of divinity in a religious newspaper, but they are thrown quite into the shade by the above, which, in fact, outdoes anything that we have met with in the same line."

Now, we admit that the editor of the Boston *Journal of Chemistry* is correct in regard to the point of fact; and this is not any particular merit, since only very elementary subjects are touched upon. But we most emphatically disclaim the propriety of the language used. We believe that science is not dependent on abuse for the vindication of truth, especially when this abuse is thrown in the face of an entire class which, rightly, is highly esteemed by the great majority of all educated and good people. If some unknown writer to the *New Jerusalem Messenger* is guilty of a sad misunderstanding of the position of a scientific lecturer, we see some cause for correcting the mistake in behalf of truth, but not the least occasion to throw a slur on the doctors of divinity, either west or east.

We should not mention this at all, if experience had not convinced us that both science and religion suffer from this condition of things. Science *must* suffer, if any of its so-called votaries insults those whom all good men delight to honor and respect, and if those who write in the name of science attempt to make people believe that science and religion are antagonistic in their very essence. That science does *not* directly suffer when ministers on the pulpit are overcome by their old Adam and declaim against science and research, we need not say; for the true minister knows well enough, that nothing can be more damaging to the cause of religion than the thoughtless assertion of some less enlightened members of their own profession, that science leads to infidelity.

It is a deplorable fact that there are a few ministers who appear to think that the cause of the Almighty depends upon the rack, the fire, or an abusive tongue; but it is, if possible, a still more deplorable fact, that some persons, under the cover of science, assault all that is holy as ignorance and superstition. We leave the former to the enlightened and reverend clergy of the day; but of the latter we say, and are ready to prove, that they do *not* speak in the cause of science and truth, but in the service of error and all that is evil.

The controversy between science and truth is already fully answered in the words, "Render unto Cæsar the things which are Cæsar's, and to God the things which are God's" (Math. xxii. 21). Here we may read science and religion instead of Cæsar and God.

So far as, indirectly, science and religion have any relation to one another, the above order is to be our guide. In no case shall anything not properly scientific, but rather theological, get into this journal under the name of science; accordingly, no statement of opinion which can give offense to any friend of religion will ever, knowingly, find a place in the SCIENTIFIC MONTHLY. Again, on the other hand, no declamations shall deter us from stating matters of fact, and principles resting on such, without inquiring or fearing what any jealous individual of any profession may think or say about it.

The propriety, or, rather, the necessity of keeping science and religion distinct, and thus prevent the exposition of compounds which lack both the confident depth of the latter, and the demonstrative clearness of the former, has been felt and insisted upon by most scientists of settled religious convictions. Thus, *Faraday* writes (Oct. 24, 1844) to a lady: —

"You speak of religion, and here you will be sadly disappointed in me. * * Your confidence in me claims, in return, mine to you. * * * There is no philosophy in my religion. * * * But, though the natural works of God can never, by any possibility, come in contradiction with the higher things that belong to our future existence, and must, with everything concerning him, ever glorify him, *still, I do not think it at all necessary to tie the study of the natural sciences and religion together*, and, in my intercourse with my fellow creatures, *that which is religious and that which is philosophical have ever been two distinct things.*"

In order to show that even the most orthodox faith and the apparently most heterodox scientific views may harmonize most perfectly, we add the remarks of Abbe *Moigno* on Professor *Barker's* lecture on the Correlation of the Vital and Physicial Forces. This lecture has, by some of the modern Protestants, been descried as heterodox, materialistic, and what not; but *Moigno*, the learned Catholic, of unquestioned orthodoxy, speaks of the lecture as follows: —

"This American lecture will seem, to many, to take very advanced ground; those of our readers who do not sufficiently reflect upon it, will see in it too many concessions to materialism; we do not hesitate to publish it, however, because, on the one hand, it is a very remarkable lecture, and, on the other, it is, in spirit (*au fond*), truly orthodox. Man is not, as the ultra-spiritualistic school would make him, an intelligence served by organs, like the archangel Raphael, the companion of young Tobias; his mind is not simply united to his body; it has the form of the body, it is completed by the body, as it completes the body; everything which acts upon the body reacts, therefore, upon the mind, as all which acts upon the mind may react upon the body. It is, then, in nowise astonishing; it is, on the contrary, very natural and necessary that the operations of the mind,—thought, will, joy, fear,—should interpret themselves in the body by a physical or physiological effect which can be estimated, and which becomes, up to a certain point, the measure, or, at east, the expression of the psychical phenomenon. Do not separate that which God and nature have united. Man is, at once, a physicial, physiological, and psychical being."

In conclusion, we state it as our firm conviction, that the student for the ministry should become thoroughly familiar with the elements of physical science, and the scientific method in general. Only thereby will such errors as those which serve as a basis for the flippant remarks of some of our contemporaries become impossible. Then no minister will, from his pulpit, denounce as false and heretic what the layman at his feet *knows* to be true and positively certain — an ocurrence which, at present, is rather more common than consistent with the interest of the Church. And, finally, no minister who has mastered the alphabet of science will declaim on the failures of science in regard to the dogmas of theology; for he would then know that science, in its very nature, has no more to do with these matters than theological dogmas with the parallax of the sun, or the crystalline form of quartz.

Only by keeping these different fields rigorously apart, can the soul find rest.

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THE LABORING FORCE OF THE HUMAN HEART.

BY SAMUEL HAUGHTON.

THERE is no organ in our bodies that has a more important influence upon health, at all ages of our lives, than the heart, whose rythm and force are governed by the laws of nerve-force, of which we are at present almost totally ignorant. Regarded, however, from a mechanical point of view, as a hydraulic pumping machine, our knowledge of the heart is more accurate, and may yet lead the way to greater knowledge of the physiological action of this vital organ.

The heart, regarded as a pumping machine, consists of two muscular bags (*ventricles*), one of which drives the blood through the lungs, and the other through the entire body. This blood is forced, by a pumping action, repeated seventy-five times each minute, through both lungs and body, and experiences, in each case, a resistance which is measured by the hydrostatical pressure of the blood in the pulmonary artery and aorta. The resistance offered to the circulation of the blood, by the capillary vessels of the lungs and body, is different; but the total quantity of blood that passes through the lungs and body in a given time must be the same; from which it follows, that the resistance offered by the capillaries must be in the proportion of the hydrostatical pressure in the great arteries leading from the ventricles of the heart. If, therefore, we knew that the pressure for one side of the heart, and the relative forces of the two ventricles in contracting, we should know the entire resistance overcome by the heart at each of its beats.

If, in addition to the hydrostatical pressure in one ventricle, and its ratio to that in the other ventricle, we knew, also, the quantity of blood forced out of each ventricle against this pressure, we should have all the elements necessary to calculate the laboring force of the heart, as will be presently shown.

Let the reader grant, provisionally, the following postulates: —

I. That three ounces of blood are driven from each ventricle at each stroke of the heart.

II. That the hydrostatical pressure in the left ventricle and aorta against which the blood is forced out, amounts to a column of blood 9.923 feet in vertical height.

III. That the muscular force of the left ventricle, in contracting, bears to that of the right ventricle the proportion of 13 to 5.

With these postulates granted, we may now proceed to calculate the daily laboring force of the heart as follows: At every stroke of the heart, three ounces of blood are forced out of the left ventricle against a pressure of a column of blood 9.923 feet in height. The work done, therefore, at each stroke, is equivalent to lifting three ounces through 9.923 feet. This work is repeated seventy-five times in each minute, and there are 60×24 minutes in the day. Hence, the daily work of the left ventricle of the human heart is $3 \times 9.923 \times 75 \times 60 \times 24$ ounces lifted through one foot; or, since there are 16 ounces in the pound, and 2,240 lbs. in the ton, the work done by the left ventricle of the heart in one day is —

$$\frac{3 \times 9.923 \times 75 \times 60 \times 24}{16 \times 2{,}240}$$

tons lifted through one foot. Reducing this, we find the daily work of the left ventricle is 89.706 foot-tons. The work done by the right ventricle is five-thirteenths of this quantity (post. III.); the daily work of the right ventricle is, therefore, 34.502 foot-tons. Adding these two quantities together, we find, for the total daily work of the human heart, 124.208 tons lifted through one foot.

It is not easy for persons unaccustomed to these calculations to appreciate quickly the enormous amount of laboring force denoted by the preceding result. To facilitate this appreciation, compare it with the following descriptions of labor: —

1. The daily labor of a working man.
2. The work done by an oarsman in an eight-oar boat-race.
2. The work done by locomotive engines, or animals climbing a height.

1. The daily labor of a working man, deduced from various kinds of labor, from observations spread over many months, is found to be equivalent to 354 tons lifted through one foot, during the ten hours. This amount of work is less than three times the work done by a single heart, beating day and night for 24 hours: thus, the hearts of three old women sitting beside the fire, alternately spinning and sleeping, do more work than can be done in a day by the youngest and strongest "navvy."

2. If an eight-oar boat be propelled through the water at the rate of one knot in seven minutes, the resistance offered by the water may be estimated at 81.36 lbs. by calculation, or, at 74.15 lbs. by actual observation. From this result, and from the fact that 575 ounces of muscle are employed by each of the eight oarsmen, we can calculate that 15 foot-pounds of

work are expended by each ounce of muscle during each minute of work.

No labor that we can undertake is regarded as more severe than that of the muscles employed during a boat-race; and yet, this labor, severe as it is, is only three-fourths of that exerted day and night during life by each of our hearts.

The average weight of the human heart, which increases with age (for obvious reasons), may be estimated from the following tables:—

1.	Meckel	10.0
2.	Cruveilhier	7.5
3.	Bouilland	8.4
4.	Lobstein	9.5
5.	Boyd (æt. 30—40)	10.4
6.	Boyd (æt. 40—50)	10.5
	Mean	9.39

From this weight, and the work done by the heart in one day (124 foot-tons), we can calculate the work done by each ounce of the heart in one minute; as follows:—

Work done by the human heart, in foot-pounds per ounce per minute, $\frac{124.208 \times 2240}{9.39 \times 24 \times 60} = 20.576$ foot-pounds.

This amount of work exceeds the work done by the muscles during a boat-race in the proportion of 20 to 15.

3. There is yet another mode of stating the wonderful energy of the human heart. Let us suppose that the heart expends its entire force in lifting its own weight vertically; then the total height through which it could lift itself in one hour is thus found, by reducing the daily work done in foot-tons (124.208) to the hourly work done in foot ounces, and dividing the result by the weight of the heart in ounces:—

Height through which the human heart could raise its own weight in one hour $= \frac{124.208 \times 2240 \times 16}{24 \times 9.39} = 19{,}754$ feet.

An active pedestrian can climb from Zermatt to the top of Mont Rosa, 9,000 feet, in nine hours; or can lift his own body at the rate of 1,000 feet per hour, which is only one-twentieth part of the energy of the heart.

When the railway was constructed from Trieste to Vienna, a prize was offered for the locomotive Alp engine that could lift its own weight through the greatest height in one hour. The prize locomotive was the "Bavaria," which lifted herself through 7,200 feet in one hour; the greatest feat, as yet, accomplished on steep gradients. This result, remarkable as it is, reaches only one-eighth part of the energy of the human heart.

From whatever mechanical point of view, therefore, we regard the human heart, it is entitled to be considered as the most wonderful mechanism. Its energy equals one-third of the total daily force of all the muscles of a strong man; it exceeds, by one-third, the labor of the muscles in a boat-race, estimated by equal weights of muscle; and it is twenty times the force of the muscles used in climbing the mountain, and eight times the force of the most powerful engine invented as yet by the art of man.—*Nature*, 1870, *Jan.* 6.

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THE DODOLO; OR, RAIN-GIRL IN HUNGARY.

THE low state of education in some of the provinces along the lower Danube is well pronounced in the custom of the *Dodolo*, prevailing in some parts of Hungary.

During a protracted drought, a poor girl is completely enveloped in green branches, so as to appear like a walking bush; this is the Dodolo. It goes from farm to farm, and sings in a monotonous manner: dodolo! dodolo! dodolo! The children of the neighborhood dance around this girl, and join in the monotonous dodolo. Soon the farmer, who has looked upon this ceremony, comes with a bucket of water and pours this, in *three* distinct portions, over the head of the dodolo-girl, while inwardly expressing his desire for rain. The dodolo-girl receives the douche with merry saltos, and, in the hot regions of southeastern Hungary, such a douche must be rather agreeable: The companion of the dodolo collects the gifts which the farmer's wife offers, such as eggs, butter, flour, and some coin.

The farmer, who has thoroughly drenched the dodolo, is sure of having performed a deed able to bring the most needed rain; and, if it happens soon after to rain, he ascribes its coming to the dodolo.

Since the dodolo only appears during a protracted drought, and, as most things here below are of a limited duration, it may be understood that the dodolo, indeed, is usually soon followed by the rain so anxiously looked for. *Probatum est.*

Have we no superstitions of a similar nature amongst ourselves, and equally at variance with the laws of physical science?

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THE ORIGIN OF METEORITES, according to STANISLAUS MEUNIER.

THE recent analysis of a piece of meteoric iron found in the Cordilleras of Deeza (Chili) has brought to light quite unexpected relations between it and two other meteorites which fell in places far remote from Chili; the one a mass of meteoric iron found in Caille, the other a meteoric stone which fell in Setif, June 9, 1867.

It may be that we have, in this Deeza meteorite, a kind of *eruptive rock*—the fragment of a larger body in which iron of the type of the Caille meteorite and a stony mass of the Setif type existed in layers, one above the other, the lower mass being afterwards forced into the upper by some eruptive force.

Attention is also called to the fact that the meteorites which fall at present do not possess the same mineralogical characters as those which fell at an earlier period in the earth's history. The old meteorites consist almost exclusively of iron; the new, of stone.

In Europe, only three falls of meteoric iron have been observed within the past one hundred and eighteen years; while it is estimated that, during the same time, there have been an average fall of three meteoric stones per year. Most of the iron meteorites met with in the mineralogical collections—and their number is, by no means, inconconsiderable—have come down to us from quite remote times; all the stone meteorites, on the contrary, are of comparatively recent date. Perhaps it would even be correct to affirm that an entirely new species of meteoric stones is, at the present period, beginning to come to us; this much is certain, that, previous to the autumn of 1803 no carboniferous meteorites were known, and since that time four such have already been discovered.

The curious statistical relations here touched upon might, possibly, be explained by supposing that meteoric irons are, in general, of rarer occurrence than meteoric stones; that even in ancient times, more of the latter have fallen than of the former, but that the meteoric stones, on account of their similarity to terrestrial rocks, are less striking in appearance, and, as a consequence, have been less frequently discovered. However, the cosmologicial conclusions, which are deduced from the relations just stated, and from the peculiar character of the meteorite of Deeza, may not be altogether unfounded.

We should mention here another argument in support of this view; viz: that iron meteorites are much more easily oxidized than stone meteorites, and that thus, being less readily recognized, they have been from the earliest times, less frequently found in proportion to the number that have actually fallen.

It is probable that meteorites are the remains of a heavenly body which, at some early epoch, gravitated around the earth, or, perhaps, around the moon; in the course of time losing its original heat, under the influence of the cold of space, it has, by reason of its smaller mass, reached much earlier than the moon those last stages of molecular action which are even now taking place on our satellite, manifesting themselves in the hollow clefts and ravines which furrow the moon's surface. Bursting asunder in all directions, this body finally fell into ruins, strewing its remains in a ring of fragments along its original orbit. These fragments took up their positions, at the same time, in concentric strata, arranged in accordance with their relative densities around their common center of attraction; — a point which they are gradually approaching, by reason of the resistance they experience in their motion through the ether. The masses nearest to the center of attraction consisted principally of iron, and were the first to fall to the earth; after these, came the stony masses, the period of their fall corresponding to our present epoch.

At a later date, meteorites will probably come to us, analagous to our crystalline rocks, and eventually, perhaps, some corresponding to our stratified rocks. The meteorites thus would be exhibitions of the last phase in the developement of planetary bodies. The sun constitutes, at present, the only representative in our system of that original condition of matter, through which the earth and all those celestial bodies which revolve around the sun have passed.

That torpid planet, the moon, presents us an image of the future in reserve for our earth, now rejoicing in the fullness of life, while the meteorites show what the dead stars become; how they fall to pieces; and how their scattered fragments are again borne into the never-ending circle of life.

After *Cosmos*, Dec. 1869, by W. C. P.

We give the above synopsis of a rather speculative paper, which has attracted some attention, and which contains much that is correct. But we think that it also contains several hasty conclusions.

Notwithstanding the assertion of *Meunier*, we believe that meteoric stones disintegrate much quicker on the surface of the earth than meteoric irons can oxidize. The latter are rounded, dense masses, and only slowly corrode on the surface; besides, only large masses have remained from remote times. The meteoric stones are always sufficiently porous to permit atmospheric air and moisture to penetrate the whole mass; the granules of iron in these stones, therefore, will oxidize, and thereby rapidly disintegrate the stone, or, at least, totally obliterate its meteoric character. We remember that our lamented teacher in chemistry, Prof. *Forchhmmer*, warned us against the conclusion now asserted by *Meunier*.

Nor would the heavier iron masses reach the earth sooner than the lighter stone masses, as *Meunier* concludes. For these masses revolve around a central body, and, therefore, the resisting medium mentioned by *Meunier* will retard the lighter stones more than the denser irons, so that the latter in their revolving motion will reach the earth much later than the stones. *Meunier* overlooks that the effect of resistance on revolving bodies is totally different from what it is on bodies simply falling toward an attracting mass in straight lines.

In conclusion, we beg to remember that complex questions of this nature must not be approached by a few isolated facts, but by all that can be brought to bear upon the same. In no case, however, can any principle of mechanics be discarded without destroying the validity of the reasonings. The above may, therefore, suffice to show that the origin of meteorites still remains an open question.—EDITOR.

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ELECTRIFICATION OF AN ISLAND.

A Curious discovery has been made by Mr. Gott, the superintendent of the French company's telegraph station at the little island of St. Pierre Miquelon. There are two telegraph stations on the island. One worked in connection with the Anglo-American company's lines by an American company, receives messages from Newfoundland and sends them on to Sydney, using for the latter purpose a powerful battery and the ordinary Morse signals.

The second station is worked by the French Trans-Atlantic Company, and is furnished with exceedingly delicate receiving instruments, the invention of Sir William Thomson, and used to receive messages from Brest and Duxbury. These very sensitive instruments were found to be seriously affected by earth-currents; *i. e.:* currents depending on some rapid changes in the electrical condition of the island. These numerous changes caused currents to flow in and out of the French company's cables, interfering very much with the currents indicating true signals. This phenomenon is not an uncommon one, and the inconvenience was removed by laying an insulated wire, about three miles long, back from the station to the sea, in which a large metal plate was immersed; this plate is used in practice as the earth of the St. Pierre station, the changes in the electrical condition or potential of the sea being small and slow, in comparison with those of the dry, rocky soil of St. Pierre.

After this had been done, it was found that part of the so-called earth-currents had been due to the signals sent by the American company into their own lines, for when the delicate receiving instrument was placed between the earth at the French station and the earth at the sea, so as to be in circuit with the three miles of insulated wire, the messages sent by the rival company were clearly indicated,—so clearly, indeed, that they have been automatically recorded by Sir William Thomson's syphon recorder.

It must be clearly understood that the American lines come nowhere in contact, or even into the neighborhood of the French line. The two stations are several hundred yards apart, and yet, messages sent at one station are distinctly read at the other station, the only connection between the two being through the earth; and it is quite clear that they would be so received and read at fifty stations in the neighborhood, all at once. The explanation is obvious enough: the potential of the ground in the neighborhood of the stations is alternately raised and lowered by the powerful battery used to send the American signals. The potential of the sea at the other end of the short insulated line remains almost if not wholly unaffected by these, and thus the island acts like a sort of great Leyden jar, continually charged by the American battery, and discharged, in part, through the short insulated French line. Each time the American operator depresses his sending key, he not only sends a current through his lines, but electrifies the whole island, and this electrification is detected and recorded by the rival company's instruments.

No similar experiment could be made in the neighborhood of a station from which many simultaneous signals were being sent; but it is perfectly clear that unless special precautions are taken at isolated stations, an inquisitive neighbor owning a short insulated wire might steal all messages without making any connection between his instrument and the cable or land line. Stealing messages by attaching an instrument to the line was a familiar incident in the American war; but now, messages may be stolen with perfect secrecy by persons who nowhere come within a quarter of a mile of the line. Luckily, the remedy is simple enough.

All owners of important isolated stations should use earth-plates at sea, and at sea only. This plan was devised by Mr. C. Varley, many years ago, to eliminate what we may term natural earth-currents, and now it should be used to avoid the production of artificial earth-currents which may be improperly made use of. FLEEMING JENKIN.

From "*Nature*," 1870, No. 27.

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THE TRI-SECTION OF AN ANGLE.

WE were not a little astonished the other day by seeing the otherwise excellent "*Polytechnic*," published at Troy, open its career with a very lengthy and, apparently, very learned article, bearing the following characteristic title: —

"*Solution and Demonstration of the Celebrated Problem of the Tri-Section of an Angle.* By Patricio M. Del Rio, of the Peruvian Treasury Department; Member of the Royal Society of Arts, London; Ex-Professor in the Peruvian Naval Academy. Translated for the *Polytechnic* by a graduate of the Class of 1867 of the Renselaer Polytechnic Institute."

We were very much astonished, indeed; for this celebrated problem is of the same class as the equally celebrated problem of the quadrature of the circle, and the construction of the perpetuum mobile.

The French academy of sciences is very often favored with solutions of these problems; but, already, long ago it resolved that all such communications be considered as if they had not been received at all. In its issue of the 11th April, 1870, it received, for example, a solution of the tri-section of the angle by one, and a solution of the quadrature of the circle by another so-called mathematician. The report is invariably: On fera savoir ä l'auteur que, en vertu d'une de'cision dejä encienne, les Communications sur ce sujet sont considerees comme non avenues.

In the interest of science, we trust that the editor of the *Polytechnic* will not discard the aid of the eminent professors whom he has so near at hand in the Renselaer Polytechnic Institute.

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FOOT-NOTES FROM A PAGE OF SAND.

BY DR. ELLIOTT COUES, U. S. A.

IF those whom fashion and the weather drive from city follies and vices to the vices and follies of the seaside; who live in hotels and carriages, and fancy the society of their kind the only sort desirable or possibe,—if such read at all by the sea shore, it is not from the broadest and most eloquent page before them. With eyes to see, blind; deaf, with ears to hear; to them, a blank, a void, beyond the titillation of social scandal. Others go out of doors afoot, looking and listening; in every object by their pathway, a familiar thing; with every vibration of the air, a well known voice; with every odor, a reminiscence. *Alone* by the sea? There is no solitude — no escape for the naturalist, even though in a weak moment he wish it, from a multitude — no disentangling of self from the web of animate creatures, of which he is one slender thread.

The sea, we know, is teeming with life — full of shapes useful or curious, beautiful or monstrous; the waves themselves, in ceaseless change, incessantly battling with the land, seem life-like; but the sand itself, solid and motionless, looks lifeless. the great broad sheet that stretches along the coast seems to be now, as it always has been, inanimate. A vast bed of silica; and yet, if not alive, what a sarcophagus it is of myriad lives since perished! If the poet says of dust in the crack of a door, "Great Cæsar's ashes here!" and attach to the mote and the man common and equal significance, yet farther than this the naturalist; for him, not the greatest pile that ever rose over emperors' remains — not the pyramids,* tombs of Pharaohs, are so great, as this monument of life that nature built — the simple sand. If ghosts be ever laid, here lie hosts of creatures innumerable, vexing the mind in the attempt to conceive, never to compute them; so minute that a grain of sand is prodigious beside. Creatures of wonderful, beautiful, varying, shapes; creatures that ate and drank, after their fashion, and went on rejoicing or grieving till the day came. Let us write a name in the sand; the wave comes — the ebb, the cradle, — the flow, the grave — of such short-lived creatures; what to these, then, that write their name in the "sands of time;" the coast of a continent their grave, the beach their monument, each sand-grain an epitaph.

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* And these, too, are of a sort of limestone, called "nummulitic," because chiefly composed of vast numbers of certain Foraminifers (*nummulites*). An ounce of Foraminiferous sand is estimated to contain upwards of four millions of these protozoans.

How long this book has been making we do not know; no man's time will suffice him to turn and read even a single page. Reflection confounds; still we may stroll on, observant, if not thoughtful; a letter, a point, an intelligible note, may catch the eye; and trifles enough have at least some pith. Say, at the moment, there is no living thing in sight. As a wave curls away from the mirrored sand, little bubbles play here and there for a few moments, and then, too, subside. Under the sand, where each bubble rose, lives a creature, encased in a shell armor, rarely seen alive, and scarcely known except by its casement, when this is thrown upon the beach; what some call a razor-shell, others *Solen ensis*. When the foot presses in yielding sand, surcharged with moisture, a slender jet of water spirts up; below is a clam (*Mya arenaria*); it dislikes the weight upon its elastic home, and remonstrates. There goes a groove in the sand, as if a child had wantonly dragged its copper-toed boot along, or some curious share had turned as curious a furrow; but the creature that made it has gone below, after what would have seemed to us, had we witnessed it, a tedious journey. Scattered here and there are large globular, yet, essentially, spiral shells of the sea-snail (*Neverita heros*); the animal that lives in them made that mark, unfolding a great fleshy "foot," and gliding along, perhaps eating something as it went, with an organ that is mouth and limb in one. Where it is now, under the sand, are plenty more mail-clad things, of all shapes, and sizes, and colors; snug and secure, giving no sign of their presence. The sand is not only a great closet of foraminiferous skeletons; it is full of flesh and blood.

But we may look for signs from above as well as under the earth, or from the waters beneath; the sand tattles many pleasant, harmless secrets, if we only attend. Here are foot-notes again, this time of real steps from real feet; the next tide will wash them out; but perhaps some one of them,—the one chance of millions—may be left to signal, centuries hence, as much as they tell now. They are wedgeshaped, and meaningless as the cuneiform characters upon a Babylonic obelisk, unless the key to the cryptogram is found; for this, the lock must first be examined to the last detail, and it is surprising how many details there are. The imprints are in two parallel lines, an inch or so apart; each impression is two or three inches in advance of the next one behind; none of them are in *pairs*, but each one of one line is opposite the middle of the interval between two of the other line; they are steps as regular as a man's, only so small. Each mark is fan-shaped; it consists of three little lines less than an inch long, spreading apart at one extremity, joined at the other; at the joined end, and *also* just in front of it, a flat depression of the sand is barely visible. So much: now following the track, we see it run straight a yard or more, then twist into a confused ball, then shoot out straight; again then stop, with a pair of the foot-prints opposite each other, different from the other end of the track, that begun as two or three little indistinct pits or scratches, not forming perfect impressions of a foot; where the track twisted there are several little round holes in the sand. The whole track commenced and finished upon the open sand. The creature that made it could not, then, have come out of either the sand or the water; as there are no fire-animals now days, it must have come down from the air; a two-legged flying thing — a bird. To determine this, and next, what kind of bird it was, every one of the trivial points of the description just given must be taken into account.

It is a bit of autobiography; the story of an invitation to dine, acceptance, a repast, an alarm at the table, a hasty retreat. A bird came on wing, lowering till the tips of its toes just touched the sand, gliding half on wing, half afoot, until the impetus of flight was exhausted; then folding its wings, but not pausing, for already a quick eye spied something inviting; a hasty pecking and probing to this side and that, where we found the lines entangled; a short run on after more food; then a suspicious object attracted its attention; it stood stock-still (just where the marks were in a pair) till, thoroughly alarmed, it sprang on wing and was off. So much is perfectly plain and intelligible; it may be not quite so easy to find out what the bird was, for we will shut the "back-stairs" door and allow no guessing, but go honestly about our induction, as if we only knew of dead birds in the closet, and had never seen a live one.

Each foot-print was of three marks only; clearly, then, made by a three-toed bird; or, if by one with four toes, the fourth was too short to reach and impress the ground visibly, or else was joined to the leg too high up. The three marks all point forward; then the hind toe, or *hallux*, as it is called, was the missing, or rudimentary one. Now, unless the bird was of a kind unknown to naturalists, which is highly improbable, it must have belonged to one or the other of two groups—the Walkers and Waders, or the Swimmers—named, respectively, *Cursores* and *Natatores*, since no bird of the only other remaining group (*Insessores*) has none, or a rudimentary hind toe.* Birds, however, cannot swim unless their feet are fashioned into paddles of some sort. We only know of this being done in two ways: either by stretching a membrane between the toes, making a webbed foot, or by fringing of the toes by broad membranes, making a lobed foot. But either of these feet, pressing the glassy sand, would have shown its pattern. Clearly, then, the bird was neither balmiped or lobiped—it was not one of the *Natatores;* it must have been a Wader. Other reasoning from a different premise, brings us to the same conclusion. The marks were not in pairs, but alternating, each with its fellow of the other line; the bird did not hop, or leap, but walked, or ran, bringing one leg after the other, whence we legitimately infer that it was not one of *Insessores* or Perchers; for these hop. But it might be asked, how do we know that the perchers hop instead of walking when on the ground, since we are agreed that we never yet saw a live one to find out by observation? Yet it is easy to reason up to such a point, that assumption is virtual certainty. For the hind toe (or each hind toe when there are two) of the *Insessores* is long, is inserted on a level with the anterior ones, and is armed with a curved claw as the others are. This arrangement is for the perfect opposition of the hind and front toes, as the thumb of our hand opposes the fingers; it infallibly suggests the idea of something to be clasped between — of grasping some object; the suggestion amounts to a moral certainty when we dissect and find among typical perchers a special muscle for the freer and more advantageous working of this hind toe in opposition to the others. Such birds, then, live where their foothold is not upon a flat surface, as the ground, but upon slender, cylindrical, claspable supports, as are found in trees and bushes. But there cannot be much plain walking done among twigs; the birds must constantly spring from one to another branch, and when they happen to descend to the ground it is not likely they would at once change a habit inborn and inbred for ages. So, with certain exceptions, not necessary to point out here, *Insessores* are hoppers, as distinctively as all birds below them are either Walkers or Swimmers.

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*To this, and all other unqualified general statements in ornithology, there are technical objections, and real or apparent exceptions, not, however, invalidating general rules.

This bird's wings never touched the sand, yet the marks show the shape of the wing as plainly as the character of the feet. The wings were flat, long, narrow, and pointed, cutting the air like blades. We learn this from the few indistinct scratches on the sand just before the prints became perfect. The bird came gliding swiftly and low, and scraped the sand before its wings were closed; to do this requires a wing large, or, at least, long. For all heavy bodied birds, or birds with wings small for their weight; or with short, rounded, and concave wings — all these, however fast they may whirr along when fairly on wing, must drop quietly if flying slowly, or arrest their motion abruptly and forcibly if flying rapidly, to avoid shock on alighting; in either case, they drop plump, and find their feet at once. Now, of all our true walking or wading birds, the *Gallinæ* (Grouse, Quail, etc.) and the *Paludicolæ* (Rails and Gallinules) conform to these last mentioned particulars; so does the Heron family, and these, moreover, have a long hind toe. It could have been neither of these. The circle of possibilities is rapidly narrowing; we have only left whence to pick, the families of birds that make up the group *Limicolæ*, or the shore-waders, as distinguished from the *Paludicolæ*, or marsh-waders. Conning the *Limicolæ* over in mind, we find there are but two families furnishing in our locality any species so small that the imprint of its toes is less than an inch long. These are the Plover and the Snipe families (*Charadriidæ* and *Scolopacidæ*).

We noticed just in front of the point where the lines of the three toes came together—at the "heel," as it is generally but wrongly called—that the depression of the heel-mark continued a slight distance between the bases of the toes.

Clearly, there must have been something of a web connecting the roots of the toes, just as our fingers are joined at the hand. Now, our plovers and snipes each furnish us one, and only one, bird that is partially webbed, and small enough to have made the tracks; these two are the Semipalmated, or Ring Plover (*Ægialitis semipalmatus*) and the Semipalmated Sandpiper (*Ereunetes pusillus*); it might have been either, for anything we have yet noticed. Which was it? We have exhausted our foot-data, but still one mark is left, and that decides. The snipes have long bills, vascular, nervous, and sensitive at the tip; these are organs of touch; the birds *feel for* things they cannot see. The plovers have short bills, comparatively hard at the tip. There were little round holes in the sand, just where the lines tangled up; this was where the little bird stuck in its bill and probed for something. It would be useless for a plover to do this, for it could not *feel* anything if it did; we infer, then, that a plover never would. And so at last, the bird stands confessed; Semipalmated Sandpiper, *Ereunetes pussillus;* section *Tringeæ*, of family *Scolopacidæ*, of group *Limicolæ*, of order *Grallæ*, of *Cursores*, of class *Aves*, or Birds.—*American Naturalist*, *July*, 1870.

REVIEW OF SCIENTIFIC BOOKS.

A Course of Six Lectures on the Chemical Changes of Carbon, by William Odling, M. B., F. R. S., Fullerian Professor of Chemistry, Royal Institution. Delivered before a Juvenile Auditory at the Royal Institution of Great Britain, during the Christmas Holidays of 1868–9.

Reprinted from the *Chemical News*, with Notes by William Crookes, F. R. S. &c. London: Longmans, Green & Co. 1869; 8vo. pp. 162.

Lectures on Animal Chemistry, delivered at the Royal College of Physicians, by William Odling, M. B., F. R. S., Fellow of the College, Lecturer on Chemistry at St. Bartholomew's Hospital, London. Longmans, Green & Co. 1866; 8vo. pp. 165.

IN no other department of chemistry has there been such marked advance during the past quarter of a century, as in that which treats of the carbon compounds. Within that period, organic chemistry, so called, has been completely revolutionized. The brilliant series of experiments conducted with unintermitting zeal by *Berthelot*, *Wohler*, *Kolbe*, and others, has completely disproved the assumption of the older chemists, that organic products can be formed only under the influence of some occult principle peculiar to living beings.

The application of the modern doctrines of Types and Substitution products to the investigation of the carbon compounds has greatly simplified their study, and has tended to attract a large share of attention to this branch of Chemical Science.

To those desirous of acquainting themselves with the latest results of investigation in this interesting field, we cordially recommend a careful study of the little volumes before us. The name of the distinguished Professor of Chemistry in the Royal Institution — chosen to fill the chair left vacant by the lamented *Faraday* — is a sufficient guaranty of their sterling scientific character.

The "Course of Lectures on the Chemical Changes of Carbon," although quite elementary — being especially designed for the instruction of the eager audience of children which each year throngs the theatre of the Royal Institution, during the Christmas Holidays — will well repay a careful perusal by older students.

A principal charm of Dr. Odling's lectures consists in the clear and concise *experimental* demonstation which accompanies each statement of fact. Each technical term, too, is defined as soon as it occurs, so that the uninstructed reader can never be at a loss to follow the lecturer in the explanation of his experiments.

The "Lectures on Animal Chemistry," delivered primarily for the benefit of a class of medical students, are, nevertheless (the lecture on uric acid excepted), more than ordinarily free from technical difficulties. We know of no other work which, in so small a compass, brings out so clearly the leading facts and principles of Animal Chemistry.

Starting with a brief exposition of Gerhardt's doctrine of Types, and the theory of Derivative Compounds, the student is carried forward, methodically and surely, to an understanding of the most complicated products of the animal organism. Everywhere, in so far as the progress of the science allows it to be legitimately done, Dr. Odling has aimed "to subordinate chemical facts to chemical principles."

For the benefit of such of our readers as may be just beginning the study of chemistry, we quote the following passage from the opening lecture: —

"We find that chemistry is daily becoming less and less a science of detail, and more and more a science of generalization; to such an extent, indeed, that, in my opinion, a student beginning the study of chemistry now, with a view to make himself acquainted with the knowledge of his day, has a far less difficult task before him than had his predecessor of twenty years ago, despite the then limited range of chemical inquiry."

The modern doctrine of the correlation of forces — especially in its relation to the phenomena of life — receives a brief but admirably clear exposition in the third and fourth lectures.

The view of the author as regards the old dogma of vital force is thus tersely expressed: —

"All the actions of the animal are traceable to cosmical force [the solar ray]; in living, as in dead matter, there is no creation of force; and any explanation of the phenomena of life which recognizes the agency of vital force is, simply, no explanation at all." On page 108, referring to the same subject, he says: "I believe that chemists appreciate, in its fullest extent, what may be termed the mystery of life; but they look upon the physiological explanation as a mere periphrasis — as only another mode of saying that dead matter differs from living matter because it is dead, while living matter differs from dead matter because it is alive. Chemists and physicists are well assured that, be life what it may, it is not a generator, but only a transformer of external force."

W. C. P.

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ELEMENTARY INTRODUCTION TO THE CHEMISTRY OF LIFE.

THE so-called *life* on the earth is represented by the *organic world*, usually divided into the *animal* and *vegetable kingdoms;* the former comprehending all *animals*, the latter all *plants*. Both plants and animals are found mainly near the surface of the earth, and in the air.* Accordingly, life is probably dependent upon both earth and air.

It is also a common observation that life is most abundant in tropical regions, so that the sun is, certainly, of great importance on life. This is most plainly evident for plants, for they thrive not except in the sunlight.

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* Aquatic animals die when the water wherein they are is deprived of air by means of an air pump.

Most animals are seen to feed on plants; so that plants are necessary for the existence of most animals. Carniverous animals are equally dependent upon plants, because their prey lives on vegetable food. It is also well known that fresh atmospheric air is necessary to the life of animals; for animals quickly die if they be placed in a space either freed of air or filled with carbon dioxide gas.

Thus, we find that animals require *vegetable food* and *atmospheric air* for their existence. Since the same materials are required to keep up a fire, it has long been supposed that animal life and a combustion are comparable. This comparison was the more probable, because, at least the higher animals keep the temperature of their body considerably above that of their surrounding, so that in the process of life *heat* is produced, as well as in a combustion.

By modern science, it has been *demonstrated* that the physical *life of animals is, mainly, a process of oxidration, or slow combustion.* The food taken into the stomach is always carbonaceous; that is, it contains a great amount of carbon, mainly in combination with hydrogen and nitrogen. For this food is readily charred, burns with flame producing water; and that it also contains nitrogen is proved by proper experiments. The oxygen necessary for *burning* the food is taken into the animal through the *lungs*, in the act of respiration. While exhaling, the resulting products of combustion are thrown out from the system. That the exhaled breath contains much water and carbon, dioxide, is readily proved by the same apparatus used in combustion. Or, we may simply breathe into a large, clean, and somewhat cool glass vessel; the dew depositing thereon proves the presence of much water (steam) in the breath. And by blowing through a glass tube, through lime-water, the white precipitate therein quickly produced proves the presence of much carbon or oxide in the exhaled air. However, the food does not burn *completely;* for a considerable residue remains in the intestines, and is evacuated in the known manner. But that portion of the food which passes *through* the walls of the intestines *into* the body is slowly burnt, giving the same products which result in an open fire.

Animal heat is produced by this combustion, which, also, is the origin and support of the muscular effort of which animals are capable, endowing them with locomotion. A living animal may, therefore, be compared not only to a burning fire, but to a working steam engine. The food is the combustible, which, burning with the oxygen of the air, yields the material products, carbon, dioxide, and water, and thereby produces also heat and mechanical power, both in the machine and in the animal. Accordingly, animal life is, essentially, a process of *oxidation;* and, therefore, a setting free of heat and mechanical (muscular) energy.

Fuel *and* Air,	*in* Steam-Engine, *give*	Carbon Dioxide, Water, *and* Heat, Mechanical Power.
Food *and* Air,	*in* Animal Body, *give*	Carbon Dioxide, Water, *and* Animal Heat, Muscular Power.

The millions of living animals and the millions of burning fires on the earth, take *oxygen* from the atmosphere and return to it carbon dioxide and water. Hence, these last two products must be found in the air.

That water is contained in the air, is well known. But it is only to a small extent due to burning fires and living animals; the sun's heat, evaporating the water from the immense surface of ocean and moist earth, gives by far the greater part of vapor to the atmosphere.

That carbon dioxide is contained in the air can be proved by making at least one lite of atmospheric air pass through a test-tube containing lime-water.

By careful experiments, it has been found that the atmosphere contains only one volume of carbon dioxide in 2,500 of air (or four volumes in 10,000 of air). By the motions in the atmosphere, this gas is very evenly distributed throughout the whole atmosphere.

[To be concluded, and to be followed by a simple course in Mineralogy for the Common Schools. It will be easily understood that the rudiments of chemistry must have been studied before presenting this subject to a class.]

SCIENTIFIC INSTRUCTION AT THE IOWA STATE UNIVERSITY.

Second Article.

The Laboratory.—First Two Years in Physical Science.*

LECTURES, review-recitations, and practice in the laboratory, under the care of the professor and assistants, constitute the principal modes of instruction in physical science at the State University. To this may, especially for the more advanced students, be added the use of the special laboratory library, which contains many of the best English, German, and French works and periodicals of physical science, and which is constantly increasing by purchases of books and the current numbers of the journals.

Besides the editor of this journal, who is professor in ordinary of physical science, two of the most promising graduates of the institution are engaged in the work of instruction. Mr. W. C. Preston, B. Ph. has already served one year as assistant, and was, at the recent meeting of the Board of Regents, promoted to the position of instructor. Mr. Frank E. Nipher, B. Ph. has been appointed assistant, after having completed the course in chemistry as far as taught at this institution.

The most characteristic features of the course in physical science here pursued are the beginning of the same at the very beginning of the college course, and the *free and compulsory laboratory practice during the first two years of the course.* The latter could only be made compulsory and free of charge after submitting the ordinary laboratory course to a most radical change, which may, perhaps, be characterized by stating that all operations are performed on small quantities. This not only reduces the expense to the institution furnishing the materials free of charge to the students, but also compels these students to become careful workers and close observers. This reform has been commenced with the view of introducing the practical or experimental study of physical science into our common schools. But, like other reforms, this one will, probably, be but slowly accomplished. But we are sure that only in this manner can physical science be taught to advantage in any school; both philosophy and experience conspired to form this conviction. We shall, from time to time, give some detail about our new method of class-experimentation, and give descriptions of the apparatus and collections used in this work. Although the proper use of materials and apparatus is free to the students, the latter must pay for whatever they carelessly destroy. But for a class of seventy in physical practice, and another of twenty in chemical work, the total sum expended in this manner amounted, during an entire term of the past year, to only five cents — a fact which sufficiently confirms the above statement, that the students become careful workers.

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* See first article, p. 23-25. We may add, that the Board of Regents have adopted the plan of study described in the first article.

In order to carry on this work, the State University possesses a large laboratory which can accommodate fifty students at the same time. This laboratory embraces the entire first story of the new building (North Hall). From the vestibule, containing the broad stairways leading up into the spacious chapel above, a large double door leads into the laboratory on the first floor. An inscription on the semi-circular transum indicates that this door leads into the "*Chemical Laboratory,*" and the well known symbols of the principal elements, around the symbols of the groups of elements, suggests the subjects studied in these halls.

The entire laboratory covers an area of nearly 3,500 square feet, and has a height of 15 feet. It is divided into six rooms, of which the Students' Laboratory is thirty by sixty feet. The rooms are well provided with cases, arranged in two stories, the lower one being eight feet high, and accessible from the floor, while the upper cases of seven feet are accessible from the gallery. These cases contain already the most necessary chemical and physical apparatus and materials, also, collections of rocks, minerals, crystals, and crystal-models.

The laboratory is also furnished with gas and water, furnaces, air pumps, balances, goniometers, spectroscopes, etc. etc.

The plans for the fitting up of these rooms were, in 1866, submitted in detail — accompanied with a large atlas of drawings — to the Board of Trustees, by the editor; the board adopted the same to be carried out, but for lack of funds, only about one-third of all the contemplated cases, etc. have been built. The rooms are, besides, becoming too small for the constantly increasing wants, so that the erection of a spacious separate Laboratory of Physical Science will be a necessity, probably, before all the details in the present rooms can be carried out.

The two years of physical science here considered are now obligatory to all students of the University not in the law and medical departments. As already stated, the student commences this study of physical science at the very beginning of his course. The following gives a synopsis of the work during these two years: —

First Year. *Elements of Physical Science*, one hour each day in lecture, or its equivalent in work. During the fall term the elements of *physics* are studied; mensuration, weighing, determination of specific gravity, demonstration of the laws of the lever, falling bodies, pendulum, friction, as well as the elements of crystalline form, light, electricity, and magnetism are studied at the students' table in the laboratory as well as in the lecture room. During the winter term the elements of *chemistry* are taken up in the same manner. The students become expert in the use of the blow-pipe, in chemical reactions, etc. but remain strangers to the chemical formula and the highly philosophical views on the constitution of matter, which grace the first pages of most books on chemistry. In the spring term the elements of *cosmical physics* are taken up. The principal minerals and rocks are studied; the various elements of the weather are determined; and the stellar constellation, as well as the *apparent* course of the planets are observed, all by each student himself, according to given directions, and under the supervision of the professor and instructors.

In this manner the student will, during the first year's course in physical science, have acquired a stock of facts and ideas which no reading, no recitation can give, and which forms the solid basis of all further progress in physical science.

So far, every common school (at least, of the grade of the grammar school) ***should take each pupil in physical science.*** The day is not distant, when this will have become, in a great measure, realized. That everybody would, one day, be able to read, to write, and to cipher, was as bold a prediction in the days of *Luther*, as the above demand is in our own day. At any rate, the work has begun in earnest at this institution, where the teachers for a great commonwealth are trained; this work has, furthermore, the cordial support of all the officers most concerned in the affairs of this institution, being especially encouraged by the president of the University and by the superintendent of public instruction, as well as by the professor of didactics. Hence, we repeat: so far, physical science *will* be taught in all the common schools of our state, at least.

It must not be thought that the costly apparatus and large halls of the University laboratory are necessary for this class in the *elements of physical science;* on the contrary, the cost, and the room required is but small. Besides, many young men and women are practically instructed in all the details of this work, and will soon be at the service of those friends of progress in Iowa and the Northwest, who may venture to introduce this work into the schools under their control.*

SECOND YEAR. *Principles of Physical Science.* One hour each day in the lecture room, or its equivalent at the work-table.

During this year there will be, relatively, more lectures and less practice. The branches of physical science are studied in the same order as during the preceding year. The study is, however, carried on in a different manner, as may

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*** The editor shall always be glad to reply to inquiries about these subjects, either through this journal, or by letter.**

already be seen from the title, the general principles of the science being deduced.

The two-years course of physical science sketched in the above lines is obligatory on all students in this university, and *introductory* to the elective and special branches of physical science taught in this institution. These studies cover four additional one-year courses, for one hour or more a day.

The detailed statement of these elective branches of physical science will be given in the next number.

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NOTES.

Our contributors at a distance have almost all asked for "more time," on account of the HEAT, which, indeed, has been excessive this season.

Professor C. A. White has favored us with an *Enumeration of the Brachipods of the Upper Coal Measures of Iowa.* It was sent to the printer to appear under the *sixth* section of the journal; viz: Original Contributions to Science. On account of the distance of the place of printing, we could not personally superintend the making up of the forms, and find this entire section omitted in this issue, much to our own regret. It will be printed in the next issue. The same remark applies to some further notices on Journals of Science.

To IRON MOUNTAIN.—The editor will join his brethren of the political press of the state on their excursion to St. Louis, Iron Mountain, and other points of interest. We shall give our readers a report of this trip if we get time to carefully examine any point on this excursion.

Am. Naturalist

THE AMERICAN

THE

American Scientific Monthly,

EDITED AND PUBLISHED BY

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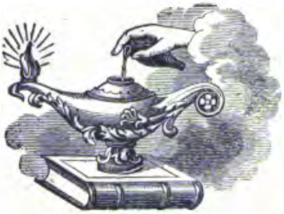

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SCIENTIFIC MONTHLY.

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NATURAL BOUNDARIES.*

I. THE VALLEY.

THE valley of the Rhine is one of the most beautiful, most fertile, and most densely populated regions of the world, and the millions which have made the valley a garden, belong to the most highly educated people of the globe. The art of printing — the great civilizer of modern days — was invented in the very center of this valley. One of the greatest of poets of all ages — the immortal Goethe — was born and grew up an intellectual giant in this valley, which also produced Schiller and Kepler. The bold declaration of Luther, the key-note of the Protestant conscience, was spoken in the middle of this same valley. And in the Alpine heights of this valley the oldest existing republic of Europe had its birth and

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*The war has detained our foreign scientific papers; the German universities are closed — the "*studenten*" have all volunteered; hence this article.

sustained the shock of the hosts of Austrians and Burgundians; while thère, where this valley is washed by the billows of the German Sea, the despotism of Phillip the Second was broken by the armed hands of the peasants, who had developed their muscular power in keeping the waves off their rich meadows. Between these two extremes of this valley, between the Alps and the Sea, the hillsides are covered with vineyards, yielding the costly Rhine-wines. Half hidden by the vines, beautiful villas look down upon the river, and on the top of the hills rise castles, towers, and grand ruins of the princely dwellings of the past. Both banks of the Rhine are closely dotted with thriving villages, pleasant towns, and grand old cities, reaching with the spires of their munsters high up into the skies.* We need only to mention Basel (Basle), Strassburg, Mannheim, Worms, Mainz (Mentz), Koblenz, Bonn, Koln (Cologne), and Rotterdam, in order to fill the reader's imagination with vivid pictures from history and life, poetry and science. In this valley we find the University of Heidelberg, that famous fount of wisdom around which the youth from all countries gather year after year. Here, also, the most famous of modern schools for painters (Dusseldorf). The singer-citizens of Cologne have won the prize at all international trials; and in Cologne we find the grandest master-piece of architecture, the pride of every Catholic, the Dome.

But we must stop this enumeration of the excellencies of the valley of the Rhine, in order not to forget the history of its inhabitants, who have so nobly used the higher gifts which nature has bestowed upon this valley. These inhabitants are *Germans*, and the valley has been inhabited by this race from time immemorial. If you listen to the peasant anywhere on the borders of this noble river, you hear none but ringing German words—*Deutsch*; and, moreover, all the essential dialects of this rich and unmixed tongue follow the Rhine in its course from the Alps to the sea. In the broken, rugged, highland country, where the Rhine has its source in the eternal snows of the St. Gotthardt, there you hear the German dialects in full-toned vowels, and short, ringing syllables, in perfect consonance with the face of the mountains and the frequent leaps of the rivers. Along the course of the river the dialect spoken remains the perfect reflex of the Rhine itself. Gay, quick, and sonorous in the middle of the valley, where the Rhine flows between the vineyards. Soft, full of deep feeling, and slow-weighed, the German words sound where the Rhine leisurely empties its waters into the deep and swelling German Sea. This one fact, the perfect harmony between the language and the country all along the Rhine, is sufficient to prove this same German people to have inhabited the region from time immemorial.

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*The tower of the munster of Strassburg is the highest tower on the globe!

Therefore nobody need to be surprised by the German claim that *the valley of the Rhine is German*—is the property and jewel of the German Nation. Hence, also, the fact that all intestine troubles among the many different tribes of this individualized nation are forgotten, and that *all* tribes rally around the national banner whenever this valley of the Rhine is threatened by a foe.

These facts enable us to comprehend how the following has become the war-song during the present great campaign. It has led thousands into death and suffering on the battle-field; but it has also brought victory to the German patriot youth, who not only have sacredly kept the *Guard on the Rhine*, but also repelled the would-be invader! We give the ringing original, and also as good a translation as we have been able to find: —

Die Wacht am Rhein.

Es brauſt ein Ruf wie Donnerhall,
Wie Schwertgeklirr und Wogenprall:
Zum Rhein, zum Rhein, zum Deutſchen Rhein!
Wer will des Stromes Hüter ſein?
Lieb' Vaterland, magſt rubig ſein,
Feſt ſteht und treu die Wacht am Rhein.

Durch Hunderttauſend zuckt es ſchnell,
Und Aller Augen blitzen hell:
Der Teutſche Jüngling, fromm und ſtark,
Beſchirmt die heil ge Landesmark.
Lieb Vaterland, magſt ruhig ſein,
Feſt ſteht und treu die Wacht am Rhein.

Und ob mein Herz im Tode bricht,
Wirſt du noch drum ein Wälſcher nicht:
Reich, wie an Waſſer deine Flut,
Iſt Deutſchland ja an Heldenblut.
Lieb Vaterland, magſt ruhig ſein,
Feſt ſteht und treu die Wacht am Rhein.

Auf blickt er in des Himmel Blau'n,
Wo todte Helden niederſchau n,
Und ſchwört mit ſtolzer Kampfesluſt:
Du Rhein bleibſt Deutſch, wie meine Bruſt!
Lieb Vaterland, magſt ruhig ſein,
Feſt ſteht und treu die Wacht am Rhein.

So lang' ein Tropfen Blut noch glüht,
Noch eine Fauſt den Degen zieht,
Und noch ein Arm die Büchſe ſpannt,
Betritt kein Feind hier deinen Strand.
Lieb Vaterland, magſt ruhig ſein,
Feſt ſteht und treu die Wacht am Rhein.

Der Schwur erſchallt, die Woge rinnt,
Die Fahnen flattern hoch im Wind:
Zum Rhein, zum Rhein, zum Deutſchen Rhein!
Wir Alle wollen Hüter ſein,
Lieb Vaterland, magſt ruhig ſein,
Feſt ſteht und treu die Wacht am Rhein.

The Rhine Guard.

There swells a cry as thunders crash,
As clash of swords and breakers dash —
To Rhine, to Rhine, to the German Rhine!
Who will protect thee, river mine?
Dear Fatherland, let peace be thine,
Brave hearts and true defend the Rhine!

To millions swiftly came the cry,
And lightnings flashed from every eye;
Our youth so good and brave, will stand
And guard thee, Holy Border Land.
Dear Fatherland, let peace be thine,
Brave hearts and true defend the Rhine!

And though my heart should beat no more,
No foreign foe will hold thy shore;
Rich, as in water is thy flood,
Is Germany in hero blood.
Dear Fatherland, let peace be thine,
Brave hearts and true defend the Rhine!

Up looked he to the heaven's blue,
Where hero-dead our actions view;
He swore, and proudly sought the strife,
"The Rhine is German as my life."
Dear Fatherland, let peace be thine,
Brave hearts and true defend the Rhine!

While yet one drop of blood throbs warm,
To wield the sword remains one arm,
To hold the rifle yet one hand,
No foeman steps upon the strand.
Loved Fatherland, let peace be thine,
Brave hearts and true defend the Rhine!

The oath resounds, the billows run,
Our colors flutter in the sun:
To Rhine, to Rhine, to the German Rhine!
We will protect thee, river mine!
Dear Fatherland, let peace be thine,
Brave hearts and true defend the Rhine

II. THE ENEMY.

Appalling is the blood that has flown in this fair garden; for on the west of it a nation dwells which, having early lost the individuality of its tribes and become centralized into *one* government, continually envies the more free individual life along this fair river, and endeavors, from time to time, by sword, torch, and treason, to bless the left bank of the Rhine by making it a part of the centralized dominion of "*La Gr-r-r-r-r-ande Nation-n-n,*" alternately the prey of demagogues and the tool of despots!

The very independence and strength of the individual tribe — the very manhood of the race — became a curse to the German nation after the glory of the German empire was dimmed by the death of Frederic Barbarossa. The powerful western neighbors sowed treason, and the dreadful carnage of German brothers began. By the religious dissensions during the thirty years war, Germany became one great battle-field. The world at large gained religious tolerance, which has since grown into freedom; but Germany, its fertile plains devastated, thousands of its men slain, was torn into shreds, held by small rulers or taken in possession by the stronger, because centralized, neighbors. The Russian held old German Baltic provinces, the Swede held Pommerania, the Dane kept Schleswig-Holstein, and France retained Alsace and Lorraine, parts of the valley of the Rhine.

At the beginning of the present century, the struggle for political freedom of the individual proved nearly as baneful to Germany as did the earlier struggle for religious liberty.

The cunning French sowed treason broadcast. Soon tribe rose against tribe; and when the French, by the aid of the Germans of Bavaria, Wurtemburg, Baden, Hessia, etc., had conquered the Germans of Prussia, the world was astonished by the *lie* of French power and French greatness. The great "French" army, part of which invaded Russia, contained only one Frenchman for every two Germans; and as soon as the different German sovereigns stopped their quarrels, the French bubble grandeur burst at Leipzig, and its fragments were burned at Waterloo.

Unfortunately, there remained *too many* princes in Germany when the boundaries of France were determined by the congress of Vienna. Hence France was not deprived of the provinces which, mainly by treason, she had torn from the German empire, and the boundary between France and Germany was not restored to the *natural boundary* between the two nations.

This natural boundary forms the western water-shed of the Rhine, and runs between the *Maass* (Frenchified into Meuse), and the *Mosel* (Frenchified to Moselle). The latter is a tributary of the Rhine, and hence belongs to the German valley of the Rhine, as also the German name of its cities (for instance *Metz*), and the language of the majority of the people still sufficiently demonstrate.

The French, with their usual regard for right, and in their well known ignorance of geography and history, claim the river Rhine as the natural boundary of France. In their attempts to make this claim good, they have so often visited the territory in question with fire-brand and savage and wanton destruction — witness the many ruins, especially in the Palatinate and Suabia — that the people most directly concerned thoroughly *know* the French. It is this thorough knowledge of the French character of warfare — a warfare hardly deteriorated by their savage auxiliary troops from Africa, known as Turcos, Zephyrs, etc. — which assisted materially in making the German tribes forget their individual claims one against the other, so as to *unite* this time against the historical foe. Hence the great astonishment of the French at the result of the present struggle. Treason was tried again, but the southern German tribes answered the French at Weissenburg and Worth in a language which even the French could most thoroughly understand.

The valley of the Rhine is German; the natural boundary of Germany runs west of this valley. The present war, if successfully completed by the united German nation, will restore the natural boundary between Germany and France. Besides, the French will have learned that they had better let other nations alone in the arrangement of domestic affairs; for the cost of this war will be so enormous that France will find it quite difficult to pay for the war (as pay she must!) which she has demanded of *William the Great*, the chief of Germany.

If, however, the French should recover from the terrible punishments they have received, the war has but just begun, and it would be folly to predict its consequences.

A few general facts must be borne in mind when weighing the probabilities of the future. Germany has, during the great migrations, sent millions of her sons away, and still there remained a nation at home. So also during the present century, an army of young men, besides thousands of families, leave every summer the native land for foreign shores — and still the country put, in less than a fortnight, a million of completely armed and well-trained men, between twenty and thirty years, into the field, and has since then sent three more great armies to the front!

France never colonized — its emigration is utterly insignificant; and still the increase in population is much smaller than in Germany. There is a great moral fact at the bottom of this statistical feature, a fact which leads to even more serious results than lack of numbers!

To a Darwinian the present struggle must be of intense interest. It is a struggle for the maintenance of the natural boundary of the two races of men — the German and the French; the Teuton and the Demi-Celt.

Finally, we may add that the current opinion expressed by the American press, according to which the present war is exclusively the work of Louis Napoleon, is erroneous. True, on this perjurer rests the curse of having commenced this slaughter of thousands of young men of both nations; but if the French people had not been ready to rush to war like a tiger that had been caged to secure public safety, Napoleon would never have dreamt of declaring war against Germany. The French consider themselves the arbiters of Europe; they forget, or have never learned, that the greatest victories of Napoleon the First were won by armies which were, to but a small extent, composed of Frenchmen; that Napoleon the First never met a united

Germany, except at Waterloo and on the plains of France, where he was defeated, and by England caged up in St. Helena — a man convicted as a disturber of the peace of Europe.

The French, as a nation, have this same tendency to disturb the peace of the continent. May their power for further mischief be thoroughly broken by their German neighbor, whom they have taunted for years; may peace again reign, at least during the remainder of this century! And the power of France for mischief will be broken, if France is reduced to the territory which the French inhabit; that is, if France be limited by its *natural boundaries.* Since the French have been claiming their natural boundaries for fifty years, we think they ought to feel thankful to William and the Germans if that wish is gratified in consequence of this war.

Then the French will have got everything exactly as they wished it. They demanded war; they have got the article, and cannot complain of the quality, which indeed is first-class — quite *extra.* They will, of course, pay for the goods they have asked for and received; the Germans keep a correct account of their expenses, and will not charge the French any more than *actual cost* for this war. The German *blood* that has flown because of this French demand for war, the French cannot pay for; but if, as a preventive of further demands of this character, France is reduced to its natural boundaries, she will have even her loudest and most boastful demands satisfied to the very letter.

◆

Since the above was written, Sedan surrendered with more than one hundred and twenty thousand French soldiers and their Emperor. The French have no longer their despot — hence they are again the prey of demagogues. A *French* Republic — the prostitution of republicanism!

FIRST CHAPTER FROM HINRICHS' ELEMENTS OF PHYSICS.

MAGNITUDE AND WEIGHT.

ALL bodies possess magnitude; that is, extension in space. The words bulk and size are, at times, used instead of the term magnitude.

Length (l), breadth (b), and height (h), measure the extension of bodies in three different directions, usually at right angles to one another.

2. The extensions in these three directions at right angles to each other are also called the *dimensions* of a body.

The third dimension, h, is called *height* when reckoned *upwards*, *depth* when reckoned *downwards*, and *thickness* when mere extension is referred to.

I. LENGTH.

3. The unit of length is the meter. The standard meter, adopted by an international committee, is preserved in the archives in Paris, and copies thereof are to be found in the archives of all civilized nations. The meter is very nearly the ten-millionth part of the arc on the earth's surface passing through Paris, due north and south from the pole to the equator.

4. This meter is the basis of the *metric system of weights and measures*, wherein the units are continually multiplied or divided by *ten*.

In this system *all measures and weights are, therefore, decimal* — exactly like the numbers we use. See examples in the subsequent (6). Hence, all calculations can be performed as with common numbers.

In older systems of measures and weights, the divisions were all at variance with the numbers we use for calculation; hence much time was lost in reducing a measure or weight from one unit to another.

These older systems are obsolete in science, and disappear more and more from common life. Many of the great nations of the continent have adopted the metric system, and made its use compulsory. England and the United States have legalized the use of the same. In science it has, as above stated, long been very generally used.

5. The *multiples* of the unit are always denoted by a prefix, derived from the *Greek* name of the corresponding number. The following are the prefixes used: —

	PREFIX.
10	deca.
100	hecto.
1,000	kilo.
10,000	myria.

The divisions, or sub-multiples, are denominated by a prefix expressing the *Latin* name of the number which is divided into the unit: —

	PREFIX.
$^1/_{10}$	deci.
$^1/_{100}$	centi.
$^1/_{1000}$	milli.

6. The names of the multiples and divisions of the unit *meter* are accordingly: —

Unit..............................1 meter.

DIVISIONS.		MULTIPLES.	
$^1/_{10}$ meter	1 deci-meter.	10 meters,	1 deca-meter.
$^1/_{100}$ "	1 centi-meter.	100 "	1 hecto-meter.
$^1/_{1000}$ "	1 milli-meter.	1,000 "	1 kilo-meter.
		10,000 "	1 myria-meter

The abbreviations most commonly used are, *m.* for meter, and *mm.* for millimeter; also *cm.* for centimeter. For example: 52 *m.* is the same as 5,200 *cm.* or 52,000 *m m.*; and 79,813 *mm.* is 79 *m.* (or 7 decameters, 9 meters), 8 decimeters, 1 centimeter, and 3 millimeters.

This example also shows how easy it is to reduce one unit to another in this system.

7. The most convenient measure for the students is a *centimeter scale*, 10 *cm.* or one decimeter long. In order to obtain the tenths or *millimeters*, an additional centimeter, divided into millimeters, has been drawn beyond the zero. The student *should copy this scale* on a strip of white card paper, about 12 *cm.* long and 1 *cm.* wide. Use this scale for measuring smaller dimensions. Also make a *meter rule*, divided into decimeters, with the last decimeter divided into centimeters. Use this rule for measuring greater dimensions. When a scale several meters long is to be used, divide the same into decimeters, and use a card millimeter scale, one decimeter long, for the determination of the *mm.* (See plate 1, fig. 1.)

If no standard is at hand, carefully mark the diameter of a nickel five-cent piece on paper, for this diameter is, according to law, 20 *mm.* It is near enough so for the beginner.

8. Practice.—The student should now carefully measure the dimensions of at least ten different objects near him, and *neatly* record these measurements in his journal (blank book). Such smaller objects to be measured by the centimeter scale are: The *inch* English measure; the length and diameter of a lead pencil; a glass rod, glass tubes, etc. Also *estimate by sight* the dimensions of such small bodies, and also of pins, nails, etc.; and thereafter measure the same, entering name, estimated and measured dimensions, in your note-book.

With the meter rule you can measure tables, cases, etc., in the school room; also the dimensions of the tables. It is best to draw a *sketch* of all objects measured, and either to enter the measures found upon this sketch, or to *letter* the sketch and tabulate the measures on another part of the paper. (See plate 1, fig. 2.)

By means of a *tape* divided into decimeters, distances in the field and garden may be measured for practice. Always carefully enter the result in your note book!

II. VOLUME.

9. The unit of volume most used in physical science is the *cubic centimeter*, and denoted *cc.* It is a cube, each edge of which is one centimeter in length.

The unit of volume used in commerce is the *litre*, *equal to one thousand cubic centimeters.* Hence the cubic centimeter is $^{1}/_{1000}$ of a litre, or a millilitre. The following table shows the above prefixes in actual use:—

Unit.....................................1 litre.

SUB-MULTIPLES.	MULTIPLES.
$^{1}/_{10}$ litre......1 deci-litre.	10 litres...1 deca-litre.
$^{1}/_{100}$ " ......1 centi-litre.	100 " ...1 hecto-litre.
$^{1}/_{1000}$ " ......1 milli-litre.	1,000 " ...1 kilo-litre.
	10,000 " ...1 myria-litre.

Many *measuring vessels* are used in physical science. In the first book we shall only require the *flask*, the *pipette*, and the *cylinder*, described below.

10. The *flask* is made to hold a definite number of cubic centimeters, when filled to a mark or ring on its neck. It is named according to the number of cubic centimeters it can hold.

A *litre flask* holds exactly 1,000 *cc.*; a 100 *cc.* flask holds exactly 100 *cc.*

11. A small test tube, supported by a large cork or a wooden foot, and provided with a scale of cubic centimeters, divided into tenths, is sufficient for common purposes. Such a tube is called a *graduated cylinder.* The *scale* is either etched into the glass, or marked with ink on a strip of paper pasted on the outer wall of the cylinder.

To read off the level of the liquid in the same, bring the eye on a level with the *concave* surface of the liquid — not with the moisture on the wall. It is also essential that the tube should be vertical while reading off. A tube holding only 5 *cc.* or 10 *cc.* is quite sufficient for many purposes.

12. It is often required to transfer a small amount of liquid from one vessel into another without handling the vessels. This can be done by means of a *pipette* or *dropping tube.*

A small glass tube, 1 deci-meter long and 2—4 millimeters in diameter, drawn out* at one end with a narrow jet, will answer very well as *pipette*, if only a few drops of liquid are to be transferred.

Hold this pipette between the thumb and second finger of the right hand, insert the jet into the liquid to be transferred, and then close the top opening with the first finger. The filled pipette may now be lifted out from the liquid, without any thereof running out of the pipette. But as soon as the finger is taken away from the top, the liquid will *drop* out from the pipette.

Not all will flow out; a column will remain in the pipette, especially if the jet be very narrow. This action of narrow tubes on liquid is called *capillarity.* It is so much the greater, the more narrow the tube.

Practice so that the contents of the pipette drops *slowly* out in separate drops, the number of which you count. By dropping into the graduated cylinder, you will find that one cubic centimeter holds from 20 to 30 drops, according to the size of the pipette.

13. At times the pipette is to transfer only a fixed quantity, say 1 *cc.* or 0.5 *cc.* A notch (filed) on the tube indicates the level at which the liquid must stand in the pipette in order to hold this amount. By gently blowing in at the wide opening, even the otherwise adhering liquid is transferred, especially if the opening be not too narrow.

If the pipette is to hold a larger quantity, it has a bulb blown in the tube.

If the pipette is also to serve as measure, a *scale* is etched on the tube, after marking to hundredths of a cubic centimeter. This constitutes the *graduated pipette.*

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*After softening the same in a good alcohol or gas flame. See Part II. If very narrow, 1—2 *mm.*, need not be drawn out at all. To cut a glass tube, draw the sharp edge of a hard file across the tube; the tube readily breaks at the place thus marked. The fracture is rounded off by a few strokes of the file while the tube is rotated between the fingers.

14. PRACTICE.—Measure the volume of a few of the vessels* near at hand, and neatly record the result in your journal. How to measure the volume of solids, see 30 and 31.

III. WEIGHT.

15. The weight of one cubic centimeter of water is taken as the unit of weight, and called a *gramme.*

Since water changes its bulk according to the degree of heat prevailing, the *law* establishing the metrical system (see 5) fixes 4° *C.* (four degrees centigrade, see Part II.) as the degree of heat at which the cubic centimeter of water is to be weighed. For *at this temperature water is more dense than at any other degree of heat.*

The divisions and multiples of the gramme are accordingly (see 5): —

Unit.............................1 gramme.

DIVISIONS.	MULTIPLES.
$^{1}/_{10}$ gr...1 deci-gramme.	10 gr...1 deca-gramme.
$^{1}/_{100}$ " ...1 centi-gramme.	100 " ...1 hecto-gramme.
$^{1}/_{1000}$ " ...1 milli-gramme.	1,000 " ...1 kilo-gramme.

The abbreviations in most common use are: gr., one gramme; mgr., one milligramme; kgr., one kilogramme. The latter is the common unit of weight in commercial transactions.

Hence, 5.21 gr. is 5 grammes, 2 decigrammes, 1 centigramme.

16. The *weights*, from the gramme upwards, are usually made of brass. These weights are to be finely gilt, to prevent their corrosion by the air, which would change the weight. The general form of these weights is cylindrical. A projecting handle enables us to take hold of the same by means of small tongs or tweezers.

The sub-divisions of the gramme are best made of *platinum-foil*, in the shape of thin, square plates. The The corners are cut off so as to be replaced by a short side about 1 mm.

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*Such as test tubes, beakers, porcelain dishes, watch glasses, etc.

The right-hand upper corner of these weights is bent upwards, to permit the weight to be taken hold of by means of ivory-pointed pinchers or tweezers.

17. For students' use, the following simple *substitutes** will answer very well indeed:—

Weights of 5, 10, 20 grammes, cut from lead bars.

Weights of 2, 1. 0.5, 0.2, 0.1 grammes, cut from sheet zinc.

A pair of common steel tweezers are used to *handle* these weights. Such tweezers can be had in every jewelry shop.

The weights are kept in a small case of wood, with holes for the reception of the several weights. The arrangement of the weights is usually thus:—

Brass	5	2	1	1	1
	10	10	20	50	
Platinum...	0.05	0.1	0.1	0.2	0.5

If the above substitutes are used, a piece of card paper (10 cm. long by 6 cm. wide) will answer well in place of this box, if the *form* and *value* of each weight is marked on the card.

18. Each weight must, after having been used, *immediately* be replaced into its own little cavity in the case, into which it exactly fits, or to its spot on the card. *The weights must never be touched by the fingers*, but be handled by means of small tweezers only.

When weighing we *read off* the weight on the scale by noticing which weights are absent from the case or card. Suppose that 20, 10, 5, and 1 be out, the weights on the scale are 20+10, or three tens, and 5+1 units; or the weight is 36 grammes, which is written 36 gr., or even 36—grammes being understood as a matter of course.

This reading is entered in the student's note book, and while *thereafter* taking off the weights from the scale pan, the written number is carefully compared with the weights themselves. Only in this manner will errors be avoided.

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*How to make them, see 23.

19. While weighing, the weights are tried in the scale pan in the order of their magnitude. Thus, if we judge the weight to be more than 20 gr. we first put on 50; it too much, 20 next; if not enough, add 10; if that is too much, put on, 5, etc., etc. This is the shortest method of weighing.

20. The common druggist's prescription scales, of brass,* is fully sufficient for all work connected with this first book in physical science.

The scale pans rest on the marble slab, while weights or substance is put on the scales. Then, in order to try the the equilibrium, the knob on the support is turned, whereby the beam is raised until one of the pans, at least, is lifted up from the slab. If the raised pan contains the weights, there are not enough weights on it yet. If the scale pan containing the burden was raised, weights have to be removed from the other pan. When, finally, equilibrium is obtained, the pointer oscillates to equal distances on both sides of the middle of the short graduated arc on the main support. Carefully comply with 18 and 19.

It is customary and advisable to put the substance to be weighed on the left scale pan, and the weights on the right pan. The case (or card) with the weights is placed conveniently near the right-hand scale pan.

If the above prescription scale (20) should be too expensive yet, a small pair of hand scales, costing about one dollar, will suffice for most problems in this first book.

21. The degree of *accuracy* sufficient in this book is: for weights to $^1/_{10}$ gramme or one deci-gramme; for volumes the same amount, or $^1/_{10}$ cubic centi-meter, and for lengths to 1 mm. That is to the first decimal. This degree of accuracy is easily attained by the means here described.

In the second book an accuracy of 0.001, or one milligramme, and even 0.0001, is frequently required; hence there a much more delicate balance will be necessary.

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*Silver plating is useless and really objectionable for laboratory purposes, since silver too quickly tarnishes in the laboratory.

22. The decimal weights and measures are embodied in the United States five-cent nickel coin, issued according to the law of 1866; for the diameter of these coins is 20 millimeters (2 cm.), which thus enables us to make a millimeter scale (7). The weight of the same coin is 5 grammes. Thereby the pupil is enabled to make a set of weights and measures for his own use.

5.142
5.072
5.037
5.032
5.030
4.950
4.926
———
Sum, 35.189
———
Mean, 5.029

CONCRETE AND ABSTRACT NUMBERS.—It cannot be expected that the weight of this coin is *exactly* 5 grammes. Indeed, by weighing, on an accurate scale, seven five-cent pieces, such as they came to hand, we found their weights as here given. The *mean* of these seven weights is 5.029, or 29 milligrammes *more* than 5 grammes.

This example shows also, strikingly, that, in *practice*, 5 is *not* the same as 5.000. Hence, *beware of writing down any decimal* not actually determined.*

23. TO MAKE A SET OF WEIGHTS AND MEASURES.—The lead weights (see 17) are easily cut out from the lead bar, in the shape of rectangular blocks with the edges cut off. First make a weight equal to the five-cent piece; then put this with the coin and balance both, thus obtaining the 10 gramme weight, etc.

The smaller weights are made from zinc sheet. Cut out a rectangular piece, 1 cm. wide, and trim its length until it balances the 10 grammes. Measure this length; cut off $^{1}/_{10}$, $^{1}/_{10}$, $^{1}/_{10}$, $^{2}/_{10}$, $^{5}/_{10}$, and you have the weights 1, 1, 1, 2, 5 grammes.

Similarly, you can make the necessary 0.1, 0.1, 0.2, and 0.5 weights.

Finally, by weighing water in a tube (see 11), we get from the same coin the weights made therefrom, or the graduated vessels for measuring volumes. The amount of water balancing one five-cent coin is evidently 5 cc. To obtain the scale (11), we need only mark the level of the water when enough has been poured in to exactly balance

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*The zero 0.0 included.

1 gramme, 2 grammes, 3 grammes, etc., until 10 grammes, and finally to divide the intervals in equal parts to tenths.

24. PRACTICE.—The student must weigh several bodies close at hand, such as small blocks of wood, pencils, pens, etc. The result must be neatly entered in the student's journal.

EXAMPLES.—Try delicacy of balance. How much turn for 0.1 gr.? How much when each pan contains 10 gr.? Accuracy for beginner, 0.05 gr. Weigh several five-cent pieces (nickel). Weigh several other small bodies. How much uncertainty in each case? Make a set of gramme weights of zinc sheet (2, 1, 0.1). Make a like set of lead rods (5, 10, 20 gr).

IV. SPECIFIC GRAVITY.

25. The weight (in grammes) of one cubic centimeter of any substance is called the specific gravity of the same, and usually denoted by the letter G.

26. Thus one cubic centimeter of water weighs one gramme (see 15); hence the specific gravity of water is *one.* One cubic centimeter of lead weighs 11.4 grammes; hence the specific gravity of lead is 11.4. The specific gravity of gold is 19.3; of mercury, 13.6—that is, one cubic centimeter of gold weighs 19.3 grammes; the same volume of mercury weighs 13.6 grammes.

PRACTICE.—Weigh a cubic centimeter of cork, wood, lead, iron, chalk, etc.

27. The specific gravity (G) of any substance can, therefore, be calculated by dividing its weight (w) (in grammes) by its volume (v) (in cubic centimeters):—

$$G = \frac{w}{v}$$

This fraction evidently gives the weight of one cubic centimeter (in grammes); that is, the specific gravity. For if v cubic centimeters weigh w grammes, one cubic centimenter weighs $^1/_v$ of w, or $^w/_v$ grammes.

28. PRACTICE.—Take several square blocks of wood, cork, etc. By measuring the three dimensions, l, b, h, (see 1) by the centimeter scale (see 8), we obtain the *volume*, v, in cubic centimeters as the product of the three dimensions: —

$$v = l.\ b.\ h.\ \text{cubic centimeters.}$$

Then weigh the block; this gives w grammes. Then calculate the fraction: —

$$G = \frac{w}{v}$$

29. If the substance be a *liquid*, pour some of the same into the graduated cylinder (11), the weight of which has first been ascertained (=a). Weigh the cylinder with the liquid (=b); then the difference (b—a) is the weight w of the liquid in the cylinder. Now read off the level of the liquid; we thereby ascertain v, its volume in cubic centimeters. Then w divided by v gives the specific gravity, G.

Carefully clean and dry the cylinder before and after use! Use a small stick, some blotting paper, a rag, etc. A few liquids are kept in small bottles (50—100 cc.) for this practice exclusively. Liquids very suitable are: *Water*, *alcohol*, *gasolene* (be careful, keep far from the light), *kerosene*; also, some saturated solutions of different soluble salts.*

30. If the substance be a *solid*, break it up into pieces that can easily be dropped into the cylinder. Fill the cylinder with water up to about 3 to 5 cc.; accurately read off the level of the water, (let it be *a* cc.) Then weigh the body; then we have w. Drop all the weighed pieces gently into the cylinder, (held somewhat inclined, to prevent loss of liquid,) and read off the level of the water again (=b). The number of cubic centimeters b—a which the water rose is evidently equal to the volume of the substance dropped into the water; that is, v=b—a. Hence the specific gravity is $\frac{w}{v} = \frac{w}{b-a}$.

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*Mercury is too dangerous for beginners.

If the substance is soluble in water, take gasolene in place of water. Remember that gasolene is highly inflammable and dangerous; so remain at very great distance from flame or fire while handling this liquid.

The solids used for this purpose are kept in small specimen tubes of about 5 cc. capacity, and properly labeled. The material is best in the shape of coarse fragments, of about $\frac{1}{4}$ to $\frac{1}{2}$ cc.

As good examples, take: *Glass* (pieces of glass rods), *sulphur*, *iron* (nails), *copper* (sheet), *zinc* (sheet), *lead* (shot or pieces). The above are all insoluble in water.

In gasolene you determine, for example, nitre, blue vitriol, alum.

Always carefully dry the substances after taking them out of the liquid.

31. The *degree of accuracy* of the specific gravity thus determined is easily ascertained. Let the *possible error* in the determination of the weight w be e, and the possible error in the determination of the volume v be e′. Then we only know that the weight is *some* value *between* w+e and w—e, and the volume some value between v+e′ and v—e′. Hence the specific gravity is some value between

$$\frac{w+e}{v-e'}, \text{ and } \frac{w-e}{v+e'}$$

By calculating these two *limits* in any given case, you can ascertain the reliability of the specific gravity determined. You will thus find that you hardly *ever* need calculate more than *one* decimal, if you use the balance and cylinder here described.

The balance used above weighs accurate to the decigramme, or to the *first decimal*; hence the greatest possible error in weight is e=0.05 grammes. Since the cylinder is divided into *tenths* of cubic centimeter, the greatest possible error in the determination of the volume is also e′=0.05. Hence the specific gravity will ordinarily be included between the limits,—

$$\frac{w-0.05}{v+0.05} < G < \frac{w+0.05}{v-0.05}$$

32. Gases are much lighter than solids. The numbers expressing their specific gravity according to 25 are, therefore, very small. The smallest of all these values is that for hydrogen, which is 0.0000896; one cubic centimeter of hydrogen weighs only this fraction of a gramme.

We state here only a few of the results obtained; in a subsequent book the weighing of gases will be treated of in detail.

33. It is very convenient to take this *weight of one cubic centimeter of hydrogen as a new unit, called one crith.* Then the specific gravity of hydrogen is one (crith). That of common atmospheric air is 14.4 crith. One cubic centimeter of air is found to weigh 14.4 times as much as the same volume of hydroden; for it weighs 0.0012932 grammes.

34. The greatest specific gravity of any yet found is that of iridium; it is 21. That of the gas hydrogen is the smallest; it is 0.0000896 only. Iridium, the heaviest substance, is hence almost 300,000 times more dense than hydrogen, the lightest body known.

Bodies thus differ very much in specific gravity.

APPENDIX.

35. Angles.—The *circle* is divided into 360 equal parts, called *degrees*, by straight lines drawn from the center. Each degree is again divided into 60 equal parts, called *minutes.*

For practical purposes, the divided circle is drawn on paper or engraved in horn or metal (brass, German silver). The simplest divided full or half circles are called *protractors;* they are sufficient for the beginner. More elaborate divided circles are used in surveying, practical astronomy, and the different branches of physics; they are part of theodolites, transits, compasses, spectroscopes, etc.

36. The simplest *goniometer* consists of two pieces of cardboard, each 1 dm. long, 1 cm. wide, and centered by a short pin. By putting a small piece of india-rubber on the pin against the card, the hinge acquires firmness.

The two cards of this goniometer are made to include the angle which is to be measured. By then applying the goniometer on the protractor, the number of degrees of the measured angle may be read off. Or the angle may be transferred to paper.

37. TIME.—At any given instant, mark the line of shadow which a vertical rod in the sun-light throws on the ground. The *time* which elapses till the shadow returns to the same line is called a *day*—so that the day is the duration of one (apparent) revolution of the sun around the earth.

This duration of the day is divided into 24 equal parts, called *hours;* each hour is again divided into 60 equal *minutes*, and each minute into 60 equal *seconds.*

Clocks have been made to accurately indicate the time in hours, minutes, and seconds.

38. A *simple pendulum* consists of a ball, suspended by a fine thread or twine. The *length* of the pendulum is the distance from the point of suspension to the center of the ball.

To find this length of a pendulum, first measure the diameter of the ball; then measure the distance from the point of suspension to the lower extremity (tangent) of the ball, and finally subtract one-half the diameter of the ball from this length.

When the pendulum is at rest, the string marks the *vertical* line. The pendulum may, therefore, be used as *plumb-line* A line or plane at right angles to the vertical is said to be *horizontal.* The free surface of water, mercury, or other limpid liquids, is horizontal.

39. When the simple pendulum has been slightly removed from its position of rest, it will *oscillate* for a long time, the ball rising on each side of the vertical to nearly the same height. The *time of oscillation* is the duration of the motion of the pendulum from its greatest distance from the vertical on the one side till it reaches the greatest distance on the other side of the vertical.

The time of oscillation is found to be exactly *one second* if the length of the pendulum is 99.4 centimeters (very nearly a meter). A pendulum of this length is called a *second-pendulum.*

40. The fundamental quantities occurring in nature have now been enumerated. All other quantities depend upon the above.

Before proceeding further, it is well to get practically acquainted with the rudiments of some branches of mathematics not usually taught in the common schools — such as the graphical determination of the trigonometrical lines, the use of co-ordinates to represent relations; also review the principles of mensuration of lines, areas, and volumes.

◆

ON THE STATICS OF CRYSTAL SYMMETRY.

At the meeting of the Imperial Academy of Sciences of Vienna, held June 23, 1870, a memoir from the editor, on the above subject, was presented. We may be permitted to translate the following from the official report of that meeting, as published in No. 17 of the *Anzeiger* of the Academy: —

"A memoir by Gustavus Hinrichs, Professor at the State University of Iowa, is presented, 'On the Statistics of Crystal Symmetry.' It rests in its final comparisons upon the totality of 2,136 numbers or species which have hitherto been investigated, often with the statement of the fundamental dimensions. In the transactions of the Imperial Academy are already the earlier enumerations by Dr. A. Weiss and Dr. A. Schrauf, prefaced by the Secretary General, von Schroetter, and another by Dr. Leander Ditscheiner.

"On account of this continuous increase of our knowledge of the separate facts, synoptical representations claim our highest interest. The author, prepared through most extensive and thorough researches, here develops on the basis of the phenomena, simple symbols, both for the expression of the crystal symmetry and for the expression of the chemical contents. The numerical statistical values have been arranged in symbols or formulæ for the different groups of crystals.

"Hinrichs gives, as results of these numbers, the following theses: 1. The more simple the chemical formula of the substance, the higher the degree of its symmetry. 2. Certain closely related atom-groups may be considered as simple. 3. The form depends not exclusively on the number of atoms, but also on the proximate constituents of the compound. 4. The hydrates proper are much less symmetric than the corresponding anhydrous compounds.

"As a general deduction, it appears that the act of crystallization favors the forms of higher symmetry. In conclusion, a graphic representation on an equi-angular hexagonal system of axes, the length of these axes representing the number of crystals known up to 1842 and 1868 is given. At the last given date, from among a total number of 1,944, there were 399 teneral, 205 hexagonal, 137 quadratic, 438 prismatic, 571 monoclinic, and 94 triclinic crystals."

◆

BRACHIOPODS OF THE UPPER COAL MEASURES OF IOWA.

BY DR. C. A. WHITE.

If the geological survey of Iowa had been continued, the intention was to prepare a descriptive catalogue of the fossils of all Iowa strata hitherto described. Very considerable collections of these fossils have been made, which, by a late law, all belong to the University. Very little progress has thus far been made in the work of classifying them, because other labors have been so pressing. Those of the upper coal measures have been most studied, and the following is a list of the *Brachiopods* of that formation in Iowa, as far as determined or identified: —

FAMILY TEREBRATULIDÆ.

GENUS WALDHEIMIA.—*King.*
    Waldheimia millipunctata.—*Hall.*

GENUS CRYPTACANTHIA.—*White and St. John.*
    Cryptacanthia compacta.—*W. and St. J.*

FAMILY SPIRIFERIDÆ.

GENUS SPIRIFER.—*Sowerby.*
    Spirifer cameratus.—*Morton.*
    S. Kentuckensis.—*Shumard.*
    S. (Martinia) plano-convexus.—*Shumard.*
    S. (Martinia) liveatus.—*Martin.*

GENUS ATHYRIS.—*McCoy.*
    Athyris subtilita.—*Hall.*

GENUS RETZIA.—*King.*
    Retzia punctulifera.—*Shumard.*

FAMILY RHYNCHONELLIDÆ.

GENUS RHYNCHONELLA.—*Fischer.*
    Rhynchonella uta.—*Marcou.*

FAMILY ORTHIDÆ.

GENUS ORTHIS.—*Dalman.*
    Orthis carbonaria.—*Swallow.*

GENUS MEEKELLA.—*White and St. John.*
    Meekella striato-costata.—*Cox.*

GENUS SYNTRIELASMA.—*Meek and Worthen.*
    Syntrielasma hemiplicata.—*Hall.*

GENUS HEMIPRONITES.—*Pander.*
    Hemipronites umbraculum.—*De Koninck.*
    H. crassa.—*Meek and Hayden.*

FAMILY PRODUCTIDÆ.

Genus Productus.—*Sowerby.*

Productus costatus.—*Sowerby.*
P. Nebrascensis.—*Owen.*
P. longispiuus.—*De Koninck.*
P. punctatus.—*Sowerby.*
P. aequicostatus.—*Shumard.*
P. semireticulatus.—*Fleming.*

Genus Chonetes.—*Fischer.*

Chonetes mucronatus.—*Meek and Hayden.*
C. verneuilianus.—*Norwood and Pratten.*

Genus Aulosteges.—*Helmersen.*

Aulosteges spondyliformis.—*W. and St. J.*

FAMILY CRANIADÆ.

Genus Crania.—*Retzius.*

Cramia modesta.—*White and St. John.*

FAMILY DESCINIDÆ.

Genus Discina.—*Lamark.*

Discina Missouriensis?—*Shumard.*

Mr. Edward S. Morse, of the Peabody Academy of Science, has lately announced his opinion that the Brachiopods *are not Mollusks*, but Articulates, nearly related to the shell-bearing marine worms. Although this announcement is almost startling, Mr. Morse supports his views with strong facts as regards homologous structure.

◆

CLASS PRACTICE IN APPLIED MATHEMATICS AND DRAWING.

In our American schools very much time is devoted to the mathematical branches of knowledge. But many years experience has convinced me that the results of this instruction are far from adequate to the time and labor expended.

Students who have for years pursued the different mathematical disciplines, have but too often been found to be entirely unable to solve the simplest concrete examples.

The reason of this deficiency on the part of the students must be sought in the fact that only the abstract principles of mathematics are taught; in too many cases it will be found that even the teachers have no practical acquaintance with the principles they teach.

How many of the students who have studied mathematics for years know the practical and very important difference between the concrete values of 5 and 5.0, or 5.00? Most will say that 5 is *the same* as 5.0000, although only the *abstract* quantities are thus equal..

Again, they have no appreciation of form. To demonstrate a proposition concerning a parallelogram, they are apt to draw a rhomb or a rectangle. Careful, accurate *linear* drawing on paper of the problems on constructions given in their books they hardly ever as much as thought of, especially the construction from given quantities. Their rough black-board work, or some uncouth penciling, is all they are usually called upon to produce—just enough to *illustrate* the repetition of the phrases given in their text-books.

We propose here to give a few practical exercises, covering some of the most important mathematical propositions and problems. We recommend these exercises especially to *teachers*, who should precede the obstruse study of *pure* (*i. e.* abstract) geometery by just such practice. The same exercises are also most useful to the many who are anxious to study physical science, but have not, in their school-days, had any opportunity for acquiring this preliminary knowledge.

The teacher needs, for this purpose, only a *balance*, with simple *weights* from 0.1 to 20 or 50 grammes; a few *centimeter rules* of card paper, embracing 10 cm., and one ad ditional centimeter, divided into millimeters, or 0.1 cm. The student thus is required to work to the *first decimal* only; that is, his possible error is one-half of one-tenth, or 0.05.

As *objects* to work upon, only a few *models*, simple geometrical figures, cut from sheet zinc, wires, etc., are needed—and easily cut by any tinner, or by the teacher himself. Also some blocks of various shapes, afterwards specified. The student needs a blank (unruled) note-book for *carefully and neatly* repording his practical work.

We shall now give a few of the more important practical exercises which each member of a class is to perform by himself. A large number of pupils can readily be kept engaged on this work, *and mostly at their own desks*; for some may draw (construct) one problem, while others may work on entirely different problems, using some or other of the models. Also insist on the students who have to use the balance to only be at the balance while actually determining the weight of the objects. All measuring, calculation, etc., they must do at their own desk. *Perfect order* is essential, as a matter of course.

We shall now first give exercises in weighing and measuration; thereafter give exercises in construction:—

EXERCISE I.

MEASURATION OF LENGTHS.—RELATION OF VARIABLES.—EQUATIONS.

Models used.—Six or eight straight wires, cut from the same piece, and from 1 to 20 cm. long; kept in paper envelopes. The teacher may have several sets of such wires, some of iron, others of lead wire, and also of different thicknesses, but not less than 1 mm. thick. As stated above, in each separate set the wires must be cut from the same piece, so that they all have the same thickness. Also put with each lot one or two wires, cut from the same piece, which are bent, so that their length cannot accurately be measured directly.

Student's work.—In your note book give the above heading; enter the date; describe the kind of wire used; arrange them in order of their length; call them No. 1, 2, 3, etc.; draw 5 vertical lines in your note book, to form 6 columns; draw line across the same; enter the headings, No., l, w, $^w/_l$, w′, e.

Under No. mark the number of each wire. Then measure each wire, and enter the length found under l; go to the balance, weigh each wire, and carefully enter the result under w; then return to your desk, and for each wire calculate the average weight per centimeter, or $^w/_l$; enter the result to two decimals, in the column so headed.

If there was no irregularity in the wire, and if the weighings and measurings had been perfect (as supposed in *abstract* mathematics), then the values in this column would all be identical. But since you had to deal with real bodies, and the accuracy of your work was only 0.05, the quotients will, at best, agree only in their first decimal. But the quotients calculated differ no more than the errors of your working; hence you have established the law that *the weight* (w) *of different pieces of the same wire is proportional to the length* (l).

It is true this result is almost self-evident; but this simple case fully exemplifies how physical laws are established by actual observation.

Take the *mean* of all values of the quotient and call this mean c; for it is the *constant* value to which the above real values approximate.

If now this weight c be taken as the most reliable weight of *one* centimeter, then you can next find the weight w′ of l centimeters by calculation:—

$$w' = c.\, l.$$

Enter the values thus found in the fifth column. These calculated values w′ should be the same as the weights w directly observed, if the real work was not subject to a limited accuracy and to errors.

Subtract the *calculated* value w′ from the *observeed* value w, and enter the difference —

$$e=w-w'$$

as *error*, in the last column.

The more accurate all work, from the models to the calculations, the less will be these "errors" or deviations.

Remarks.— In "pure sciences," such as the *abstract geometry* and mathematics of our schools, no such deviations are recognized. The *real work*, however, from the building of a vertical wall, to the construction of a railroad bridge and the adjustment of a chronometer, are subject to just such deviations between the *abstract* thought and the *concrete* reality. The student should early become acquainted therewith, and *learn to ascertain the probable limit of the magnitude of the errors;* because only if this limit is known, we know the degree of accuracy we have attained to — or, in other words, *we know how much reliance should be given to the final result.**

General results.—The lengths cut off are mutually different; so are the weights found. Quantities which thus change or vary together from one case to another are called *variable quantities*, or simply *variables.* The quotient c did *not* change; such a quantity is called a *constant.*

By $w'=cl$. you find the value of w′ by means of the value of l; hence, in this case, w′ is called the *dependent variable*, while l is the *independent variable* quantity.

Any such *equality* between different quantities, expressed in a general way (by letters, etc.), is termed an *equation.* Translate the equation occurring in this exercise into words.

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*Thus, a surveyor may report the area of a meadow measured by him with three or four decimals attached to the number of acres. You need only to have the meadow re-measured in order to learn what confidence these decimals deserve.

Conclusion.—In this simple exercise we have exemplified the *method of physical research*, as it is used in modern science. First we obtained, by *direct observation*, both variables, weight, w, and length, l; thereafter we found that these variables were dependent one on the other, for w divided by l was (approximately) constant. We then reversed the operation, by considering this relation an established *fact*, a *law*. The mean value of the constant c was multiplied by the length l, and thus the weight w′ obtained by *calculation*. We finally compared these calculated values with those obtained by direct observation, and thus ascertained the *degree of accuracy* of our work in the values of e, by which w′ differs from w.

If we had put one of the wirès aside, and now *measure* the same, we can calculate its weight; or, if we weigh the same, we can calculate its length. Thus a law once established is *applied* to the determination of unknown quantities. Try it for the curved wire of the models.

[To be Continued.]

◆

AT the opening of the State University, on Wednesday, September 15, there were about three hundred students present, of whom one hundred were new ones; which is about *seventy-five* more than last year. There were about forty in the Law, and over twenty in the Medical, department; while the classes in Natural Philosophy (Physics) already number more than two hundred students. The prospects of the University are indeed flattering. It starts out this year complete in all its departments, as a University in fact.

EDITORIALS.—All articles in this Monthly, not otherwise credited, have been written by the editor. This in answer to many questions.

American Naturalist

THE

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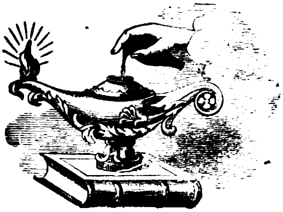

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THE ROYAL RHENANE-WESTPHALIAN POLYTECHNIC SCHOOL AT AACHEN.*

BY VON KAVEN, DIRECTOR.

I. *Organization in general.*

THE Royal Polytechnic School at Aachen is a *Technical High School*, possessing the same civil privileges as the Polytechnic School of Hanover, the Berlin Academy of Architecture, and the Industrial Academy at the same

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*This new school will open in October, this year — provided the war had closed by that time. It is located at the old imperial city of *Aachen* (Aix-la-Chapelle). We have before us a view of the grand building — a magnificent palace — which has been specially erected for this school.

When we look at the *chain* of schools, from the Kindergarten to the University and Polytechnicum, then we first begin to appreciate the thoroughness of German education. How much remains to be done in this country in this direction!

We have had the *official* announcement specially translated for the AMERICAN SCIENTIFIC MONTHLY, in order to show the matter-of-fact statements made, and to make the public somewhat acquainted with the German Polytechnicum — schools which, as yet, we have but traces of in this country. This special and official information will be particularly useful at this time, when agricultural colleges and industrial universities are so much talked of. See the article on "*Technical Instruction in Europe*," which follows this paper.

place, and stands on an equal footing with these institutions.

Besides a general scientific school, it embraces also three professional schools (fach schule), viz.: A professional school of architecture and civil engineering; a professional school of mechanical technology and the construction of machinery; and a professional school of chemical technology and metallurgy.*

In the general school, the subjects of study are the *Natural Sciences* and *Mathematics*, and such branches as are required for admission to the professional schools.

The complete course of study for architects and engineers embraces four years, viz.: one year in the general scientific school, and three years in the professional school.

The studies of the first three years are the same for both architects and engineers, and their completion exempts the student from the Prussian government examination, which candidates for the profession of superintendent of the construction of buildings (baufuehrer) are required to pass.

The studies of the fourth year differ accordingly as it is desired to give further special attention to architecture or engineering, and absolves the student from the Prussian governmental examination for master-builders (baumeister.)

The entire course of study in the school of machine building and mechanical technology covers four years, viz.: one year in the general school and three in the professional school.

It is possible, however, by two years study in the professional school, to complete the preparation in those branches in so far that the student can then have the choice, either of acquiring, within the school itself, a further knowledge of construction, especially a more thorough familiarity with the studies of the fourth year, or of obtaining the same result by his study while going out to the practice of his profession.

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*It will be seen from this that Law, Medicine, and Theology do not alône constitute the learned professions in Germany.

The course of study for chemists and metallurgists covers, in all, three years, of which two are in the professional school.

Those who desire to prepare themselves for *teachers* in the industrial schools, and in the higher technological institutions, can take up such of the studies of this institution as they may desire, and will require, according to the degree of qualification they seek to attain, a period of study of from three to four years — one year of which is included in the general school.

By way of explanation, it may be stated here that students in the professional school of architecture and engineering will receive that special instruction which is necessary to fit them for technicians in architecture, and in the construction of railroads, streets, water-works, and bridges, to qualify them as surveyors, etc.; in the professional school devoted to machine construction and mechanical technics, students will be fitted for positions as engineers of machinery, superintendents of mechanics, technological establishments, e. g. spinning and weaving factories, machine works, &c.; and also technicians in railroading. In the professional school of chemical technology and metallurgy, students will be prepared for business as practical chemists, superintendents of chemico-technological establishments, (dyeries, chemical manufactories, etc.), and also as superintendents of metallurgical works.

II. *Subjects taught.*

The subjects taught are briefly enumerated below:—

A. *Ordinary Lectures.*

1. Higher Mathematics, I.
2. Higher Mathematics, II.
3. Higher Mathematics, III.

4. Descriptive Geometry.
5. Mechanics, I.
6. Mechanics, II., and Engineering Mechanics.
7. Geometry of Position and Graphostatics.
8. Practical Geometry, I.
9. Practical Geometry, II.
10. Practical Geometry, III.
11. Construction of Machines, I.
12. Construction of Machines, II.
13. Description of Machines.
14. Theory of Machines, I.
15. Theory of Machines, II.
16. Cinematics.
17. Regulators.
18. Exercises in Construction.
19. Mechanical Theory of Heat.
20. Architectural Technology..
21. Mechanical Technology, I.
22. Mechanical Technology, II.
23. Architectural Mechanics.
24. Architecture of Manufactories.
25. Management of Industrial Enterprises.
26. Architecture, I.
    - A. Architectural Constructions.
    - B. Antique Architecture.
    - C. Practice in the construction of simple structures.
27. Architecture, II.
    - A. Higher Constructions.
    - B. Theoretical Architecture and Perspectives.
    - C. Agricultural Architecture.
    - D. Ornamentics, I.
    - E. History of Architecture.
28. Architecture, III.
    - A. Designing of Larger Buildings.
    - B. Interior of Buildings.

- C. Details of parts of Buildings.
- D. Building Materials, Specifications, and Superintendence.
- E. Ornamentics, II.
- F. History of Architecture, II.
- G. Medieval Architecture.

29. Architecture, IV.
    - A. Heating, Ventilation, etc. of Larger Buildings.
    - B. Important Private and Public Buildings, and Town Improvements.
    - C. Designs of Public Buildings.
    - D. Parts of Buildings with Colored Architecture.
    - E. Ornamentics and Smaller Structures.
    - F. Medieval Architecture.
    - G. History of Architecture, III.
30. Elements of Hydraulics. . .
31. Hydraulics, II (in general).
32. Elements in Bridge-building.
33. Bridge-building, II (in general).
34. Elements of Highway and Railroad Building.
35. Highway and Railroad Architecture (in general).
36. Architectural Mineralogy.
37. Mineralogy.
38. Crystallography.
39. Geology and Paleantology.
40. Mineralogical Practice.
41. Crystallagraphical Practice.
42. Elements of Physics (Architectural Physics).
43. Experimental Physics.
44. Physics with Mathematical Demonstrations.
45. Applied Physics, with practice in the Physical Laboratory.
46. Elements of Chemistry (Architectural Chemistry).
47. Pure Chemistry.
48. Technical Chemistry.
49. Analytical Chemistry.

   - A. Qualitative Analysis.
   - B. Quantitative Analysis.
   - C. Volumetric Analysis.

50. Practical Chemistry.
   - A. Practical Exercises in the Analytical Department of the Laboratory.
   - B. Practical Exercises in the Laboratory of Technical Chemistry.
51. Electric Telegraphy.
52. Metallurgy and the Smelting of Iron.
53. Carbonization and Coking.
54. Management of Salt Works.
55. Mining Assaying.
56. Planning of Factories and Metallurgical Works.
57. Embossing and Modeling.
58. Free-hand Drawing.

B. *Extraordinary Lectures.*

Announced for the course of 1870–71 : —

1. Elliptical Functions.
2. Theory of Algebraic Curues.
3. Mathematical Theory of the Elasticity of Solid Bodies.
4. Motions of the Planets.
5. Electro-dynamics and Electro-magnetism.
6. Theory of Polanization and Double Refraction, with especial reference to Saccharimetry.
7. Saccharimetry, with Practical Exercises.
8. Gas Analysis, with Practical Exercises.
9. Exercises in the Determination of the Illuminating Power of Gas.
10. Taxicology.
11. Technical Study of Forms, for Engineers, Architects, and Machinists.
12. Brewing of Beer.
13. Manufacture of Beet Sugar.

Also, lectures on the German, French, and English languages and literature, Geography, and National Economy.

III. *Corps of Instructors.*

The professors in this institution, thus far appointed, are as follows: —

Professors in Ordinary: Government surveyor (Baurath) von Kaven (formerly teacher in the Polytechnic School at Hanover, and assistant director of the railroads of Hanover), as Director of the entire school, and teacher of Highway and Railroad Construction; Prof. Dr. Heinzerling (formerly Professor in Ordinary of the Sciences of Architecture and Engineering at the University of Giessen), Bridge-building, and the higher departments of Architectural Construction; Engineer Intze (formerly a member of the directory of water works in Hamburg), Hydraulics; Prof. Dr. Landolt (formerly Professor in Ordinary at the University of Bonn), Chemistry; Dr. Stahlschmidt (formerly teacher in the Industrial Academy at Berlin), Technical Chemistry; Dr. Laspeyres (formerly *docent* in the Mining Academy at Berlin), Mineralogy and Mining; Architect Ewerbeck (of Osnabruck), Architecture; Architect Tochtermann (of Hildesheim), Architecture; Engineer Hermann (formerly a member of the Berlin Industrial Direction), Technology; Engineer von Gizycki (formerly tutor in the Industrial Academy of Berlin), Science of Machines; Prof. Lewicki (of the Baltic Polytechnic School at Riga), Construction of Machines; Dr. Helmert (formerly Observer in the Astronomical Observatory at Hamburg), Geodetics; Prof. Dr. Ritter (of the Polytechnic School at Hanover), Mechanics; Dr. Hattendorff (of the High School in Hanover), Mathematics; Prof. Dr. Reye (of the Polytechnic School at Zurich), Descriptive Geometry and Graphostatics; Prof. Dr. Wullner (of the University of Bonn), Physics; Dr. Classen (of Aachen), Assistant Instructor in Chemistry; Dr. Herwig (of Bonn), Assistant Instructor in Physics.

Besides the above, there will also be appointed teachers in Extraordinary and assistants—so that the entire corps of instructors will consist of about thirty persons, not counting the private tutors (*privat docenten*) which may locate here.

IV. *Classification of Students, and Admission to the Institution.*

Persons attending this Institution will be distinguished as "Students," "Auditors" (zuhoerer), and "Guests" (hospitanten.)

Any one is entitled to admission as a *student* in the General Scientific Department on presenting a certificate of one year's attendance at the "prima" of a gymnasium, or at a "*real* schule" of the highest grade; or on presenting a certificate of having completed the course of study in a provincial industrial school conducted on the modern plan. Pupils of provincial industrial schools under the old management will, until further notice, also be admitted into the Institution, on presenting a certificate of graduation. Those who have not been prepared at one of the above designated schools, will be expected to furnish proof of the necessary preparation in some other way (if necessary, by an examination); in addition to this, he must produce a certificate of a good moral character. Foreign students can, in special cases, be excused from presenting proof of preparation.

Students of the Royal Industrial Academy, of the Royal Academy of Architecture, and of the Royal Mining Academy in Berlin, as also students of the Principal-School of the Royal Polytechnic School at Hanover, and technicians who have passed their examination as building superintendents, or as bergeleven for government service, are entitled to admission to this institution without further evidence of preparation.

The privilege of admission to the one-year's voluntary service in the army is, by royal decree, granted to the students of this polytechnic school. * * * *

The admission of students who have attended other than the above named polytechnic schools and academies, may be made to depend on the evidence of sufficient preparation.

Those entering as "auditors" are not, in general, required to satisfy any conditions of admission; nevertheless, in certain cases, their admission may also be made dependent on proof of satisfactory preparation.

In order to attend the institution with profit to himself, and to be able to follow the lectures, it is necessary for the learner to posses so much knowledge of mathematics and skill in drawing as may be acquired in one year's attendance at the prima of a gymnasium.*

"Guests" (hospitanten) include such auditors as, being mostly of mature age, desire to prosecute only especial branches of study.

The distinction between "students" and "auditors" consists in the circumstance that the former, on making request, will receive a *testimonial*, which is, in general, limited to a certificate of having attended certain lectures and exercises; but, if desired, this testimonial will also express the result obtained. "Auditors" receive no *testimonial*, but only a certificate of having attended certain lectures and exercises. As announced more fully below, their tuition fee is somewhat higher than that for students.

V. *Plan of Study.*

Students choose for themselves which of the professional schools they will enter. They are, likewise, unlimited in the choice of lectures and exercises. The same is true for auditors.

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*Accordingly, there will be pre-supposed, in particular, a knowledge of elementary Arithmetics and Algebra, especially in powers and roots; the theory and use of logarithms, equations of the first and second degrees; also a knowledge of Planimetry, Stereometry, and Trigonometry.

Hints for a correct course of professional study will be found in the programme of the plan of studies for architects, engineers, machinists, chemists, miners, teachers in industrial schools, etc., shortly to be published.

Moreover, each one, according to his own special needs and the number of years he expects to spend at the university, can make out his own plan of study by means of the programme of daily lectures and exercises and the assistance of some one of the instructors.

VI. *Admission Fees and "Honarare."*

Students are required to furnish themselves with a matriculation card, the fee for which is one thaler, and which entitles them to attend the institution. *Auditors* and *guests* receive such a card gratuitously.

Attendance at the lectures must commence within fourteen days of the beginning of the term, up to which time it is free. The formalities to be observed on admission will be announced in the programme.

The "honorar" (lecture fee) for "ordinary" instruction must be paid semi-annually, in advance, and will be determined according to the number of hours of instruction attended each week during the semester. *Students* will be charged for each course of one hour lectures two-thirds of a thaler; for each course of exercises, one hour per day, one-half thaler. Auditors will be charged for the former one thaler; for the latter, two-thirds of a thaler.

Since the maximum number of hours (at lectures and exercises) required of a polytechnic student is thirty-six per week, the maximum tuition fees, supposing there is on an average as many hours of exercises as of lectures, will amount for each *student* to twenty-one thalers; for each auditor, to thirty thalers per semester. Besides the above, there will be an incidental charge for participation in the practical exercises of the chemical laboratory of fifteen thalers; for the physical exercises, fifteen thalers per annum.

The fee for the "extraordinary" lectures is not fixed, and is different for each course.

Students, however, bringing a certificate of indigence, can be exempted from the usual fees, either entirely or in part, in so far as they distinguish themselves by progress and good behavior. In such cases, also, credit may be allowed for the period of one year.

VII. *Scholarships (Stipendien).*

The "Frederic-William Foundation" gives scholarships of two hundred thalers each per annum.

* * *

VIII. *Time of Opening.*

Instruction in the institution begins in the first part of October (for the opening year on the 10th of October), and closes on the 31st of July of each year. There is a Christmas vacation of two weeks, and an Easter vacation of three weeks. The examination of those students who cannot present the required certificates of qualification for admission, will take place from the 3d to the 8th of October; the registration of other students and of auditors will be had October 3d. Students are only admitted, as a rule, in autumn, at the commencement of the school year; in exceptional cases they may be admitted at Easter, provided they possess the requisite knowledge to follow further instruction. Auditors may be admitted to the institution at any time.

IX. *Auxiliaries of Instruction.*

The auxiliaries of the institution consist of a finely furnished physical cabinet and laboratory; an excellent mineralogical and paleontological collection, and collections for the various branches, and also a large library.

The chemical laboratory occupies a building separate from the principal edifice; its plans and appointments correspond to the demands of the present time. The institution will accommodate, at present, about five hundred students; the laboratory about sixty.

X. *Residence at Aachen.*

[A few remarks on the city, the many important technical establishments in and around the same, which it is not necessary to give in detail.]

A register of suitable rooms may be found in the institution.

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TECHNICAL INSTRUCTION IN EUROPE.

ONE of the most valuable of the recent issues from the government printing office, at Washington, is the volume on "Technical Instruction," which appears as a special report of the Commissioner of Education, prepared by Dr. Henry Barnard, in pursuance of a call by the House of Representatives, January 19, 1870, for information on the subject.

This volume was designed as a part — part fourth — of a series of six parts, embracing all possible information and statistics in relation to elementary, collegiate, technical, professional, and supplementary instruction, as well as an account of all the museums, collections, and societies for the promotion of education, science, literature, and the arts. In the time necessary to perfect so comprehensive a scheme, it is not strange that our ephemeral Congress grew impatient, and desired to see something tangible; hence the publication of this volume of nearly eight hundred closely printed pages, which is published at the request of Dr. Barnard's successor, General Eaton, the present Commissioner of Education.

It is incomplete, wanting the chapters on Great Britain and the United States, but it contains such a mass of valuable information as to inspire the earnest hope that General Eaton will find some way to request the publication of the other parts of the proposed scheme, and so gain for the government of the United States the credit of issuing these results of the life-work of the citizen who has done so much towards disseminating information about educational matters over the land.

But while we may justly take pride in that this is the result of the labor of an American who knows more, probably, of the state of education in all the countries of the civilized world, than any other person; and while we may point to it with pride, as a public document, there is in its contents little food for our vanity; nor, as we turn over its pages and see what the smaller countries of Europe are doing, will it serve to raise our self-esteem to recall how narrowly the National Bureau of Education escaped destruction this spring, at the hands of our intelligent Representatives, nor how the votes of only two Senators saved the Bureau of Education of this good State of Connecticut, last Thursday week.

There is another view that will not tend to increase our natural and national vanity, and that is, that while we have been making such a wonderful to-do over two or three schools of science, and reverend and learned Doctors of Divinity pronounce great orations in honor of the "New Education," we find in the pages of this monitory book, that little provinces of Europeon states have for a lifetime had more and better technical schools — "scientific" we call them — than we can yet boast in all America.

Forced to admit that they have beaten us in general scientific and special technical education, we, however, fall back upon our unrivalled system of public education, and talk about the glory of our common schools, where every poor man's son can, without money and without price, learn enough to make him fit to be President; — this test, by the way, being variable, and utterly unscientific — but a little incidental reading in these pages will soon convince us of our utter inferiority to the subjects of tyrants and despots in this, our strongest point.

In fact, the average American who looks into this book will find himself in the condition of the English visitors to the Paris Exposition of 1867, who suddenly found that England's fancied superiority in manufacture was a delusion, and that since 1850 the other nations had trained up a generation of educated artizans, who were excelling her in every department. He will learn first that this "New Education" is at least a century old; second, that our oldest, best trained States are, in respect to the thoroughness and extent of the education they offer their citizens, far behind many of the little German principalities, or some of the Swiss cantons.

If this be so under the shadow of the walls of Harvard and of Yale, what must it be in those just forming Western communities, or those reconstructing Southern States?

President McCosh, in his remarks before the Alumni, touched upon the one great want, so felt by his college, that of a higher order of fitting schools throughout the State of New Jersey,—a want felt in a less degree by our New England colleges, but *felt* everywhere.

The higher institutions of learning depend then upon the lower — the excellence of the college on that of the common school. So this interdependence runs through all. The arts, the sciences depend for their development upon the intelligence of the *ouvrier.*

The position of a country in the great family of nations depends upon the education of its common people; competition runs so close, that the country which has the trained, skilled workmen is the superior; nothing can long compensate for the want of these. Self-preservation, the first law of nations as of individuals, will force the State to the education of all its citizens. Science, the handmaid of all the industrial arts, must heed their behests.

To know what can be done, we have but to learn what others have done; to know what must be done, we have but to know what others are doing. In the matter of scientific and technical education, both of these facts can be found in the pages of Dr. Barnard's report.—*The College Courant, August* 6, 1870.

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CLASS PRACTICE.—Continued.

EXERCISE II.

PRACTICAL MENSURATION OF AREAS.

Models used.—Various geometrical figures, such as triangles, parallelograms, and other polygons of different shape and size, and a few irregular curvilinear forms, *all* cut from the same piece of sheet zinc or sheet brass.* The greatest dimension used should be about 15 cm. Keep 6 to 10 such models in an envelop of strong paper, and hand this to the student to work with. The teacher must first have ascertained that these models are really all of uniform thickness, or that their weight really *is* proportional to their area. Also have the models in each package *numbered*, for the sake of reference.

Student's work.—Enter the proper heading and date in your note book; state the *material* of the models; take up the models in order of their number; *describe* each model

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***Be careful to have these figures cut accurately, and from the middle of the sheet; the margins are usually different in thickness.**

under its own number, by giving the *name* of the form and its *dimensions*, as resulting from your own measurements. You best also carefully make a *sketch* of the model in your note book, letter its corners A, B, C, etc.; draw necessary diagonals, etc., with dotted pencil lines, on the sketch, etc. Then you simply record the dimensions by enumerating the same on the right of the sketch by letters, as for instance:—

A B=15.3 cm.
B C=7.6 cm.

Then *calculate the area* a from these measurements. For this purpose remember the following:—

1. The area, a, of any rectangle or any parallelogram is the product of its base, b, and its height, h. $a=b\,h$.

2. The area of any triangle is half the product of its base into its height. $a=\frac{1}{2}\,b\,h$.

3. Any other polygon you must suppose divided into triangles, and then measure the base and height of each of these triangles; the *sum* of the areas of all these triangles then constitutes the area of the given polygon. Since each polygon can be supposed to be divided in two and more sets of such triangles, you can *check* your work, by making at least two independent determinations for each polygon.*

Next weigh the model; this gives w grammes. Then divide w by a, which gives you the calculated weight for each square centimeter.

Do all this with each of the models. Then sum up the results in a table of seven columns, containing, from left to right: Number, name, area (a), weight (w), weight of one square centimeter ($^{w}/_{a}$).

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*In order to simplify this work, the teacher better accurately scratch the dividing lines in the model by means of a sharp point. The two sides of the model thus give the two sets of divisions ready for students' use. On the one side you may divide by diagonals only, giving scalene triangles; on the other, by one diagonal and perpendiculars thereto, so as to divide this side of the polygon into right angled triangles and trapezoids.

The last values are again all nearly equal, if the material for the models had been carefully selected. Therefore take the *mean* of all these values; call this c. Then calculate the weight $w'=c.\,a.$; enter this value in the sixth column. In the seventh place the error e $w - w'$. See 41 and 42 for further explanations.

If this work has been done carefully — as all work *must* be done — these errors will be found to be but small. You may then *calculate* the area of the *irregular and curvilinear models* in the envelop, by weighing the same, and dividing the weight by c. Why?

EXERCISE III.

MENSURATION OF THE VOLUME OF SOLIDS.

Models used.— From the same piece of wood have carefully made several blocks, such as cubes, square and oblique parallelopipeds, prisms of various shapes, and also pyramids; finally again a few more or less irregular bodies, which it would be nearly impossible to directly measure. The greatest dimensions need not exceed 10 or 15 cm. Keep a set of such blocks in a wooden box; have the blocks in each box numbered.

The *student's work* is now precisely as in the preceding exercise — only that here he measures the *base* (b), by the process given in that exercise, and then measures the *height* (h), whereby the square rule often is of great use. He then must remember: —

1. The volume (v) of any prism is the product of the base and the vertical height. $v=b.\,h.$
2. The volume (v) of a pyramid is *one-third* the product of the base into the height. $v=\frac{1}{3}\,b.\,h.$

Application of these methods to Elementary Geometry.— The propositions demonstrated in abstract geometry may readily be established as physical facts by means of the balance and good models cut from sheet metal. We shall give but a few of these important exercises for beginners, and for those more advanced students who have had no practice.

EXERCISE IV.

THE AREA OF SIMILAR FIGURES IS PROPORTIONAL TO THE SQUARE OF THEIR HOMOLOGOUS LINES.

Models.— Also here several different sets of four to eight models each, may readily be procured by the teacher; say one set of squares, another set of similar triangles, and a set of similar but quite irregular pentagons — each set kept in a separate strong envelop.

Student's work.— The student, having received some one set, enters the usual preliminaries in his note book, and thereafter first convinces himself that the figures are really similar; secondly, determines their weight; finally, finds the relation between this weight and the homologous dimensions. All models having been cut from the same uniform sheet zinc, these weights are proportional to the area, as has been shown in 42.

For the sake of completeness, it is well to have a rectangle, say 2 by 5 centimeters, to directly determine the weight, c, of one square centimeter, in order to actually reduce the observed weight, w, to the area, a, by dividing w by c for each model. (See 43.)

First, to ascertain whether the models really are *similar* figures, the student enters a carefully drawn sketch of any one of them in his note book, and *letters* the corners in this sketch for sake of easy reference; then places all models before him in a like position, so that the homologous parts will be denoted by the same letters.

Hence *the homologous angles must be equal, and homologous lines must be proportional, in order that the figures may be similar* (Definition).

The student ascertains the equality of the angles by direct superposition; and states the results of his observations in the note book.

To ascertain the proportionality of the homologous lines requires more work. First *measure* on one model as many lines, such as the sides, A B, B C, C D, etc., and diagonals, A C, A D, A E, etc.; also B D, B E, etc. etc.—in fact, as many as are deemed necessary. Enter these results in a table like this:—

LENGTHS IN MODEL.

Line.	No. 1	No. 2	No. 3	etc.
A B....	....	....	....	....
B C....	....	....	....	....
Etc.				

Then divide all these values by the values found for any one, say for No. 1; enter the quotients or ratios thus obtained in a like table, under the heading,—

$\frac{\text{No. 2}}{\text{No. 1}}$	$\frac{\text{No. 3}}{\text{No. 1}}$	$\frac{\text{No. 4}}{\text{No. 1}}$	etc.

Then, if the figures investigated are really similar, the ratios in any *one* vertical column must be very nearly the same. You can draw a line below, and take the mean of each. This, then, is the most exact value of the *ratio* between the homologous lines in No. 2 and No. 1, No. 3 and No. 1, etc. Of course you might also determine, in the same manner, the ratios No. 4, No. 2, etc. etc.

Next multiply these ratios by themselves, and enter this value as the *square* of the ratios below the ratios themselves at the foot of the columns. Draw another line across the table. Weigh each model, and enter the result in your note book. Divide these weights in the above manner, such as weight of No. 2 divide by weight of No. 1, etc. Enter these *ratios of weights* in the corresponding table;

or, better, repeat the form of table, enter the ratios of weight, and mark the ratios above found, as well as their square, below the same.

You will then find that the *ratios of weights are very nearly the same as the squares of the ratios of homologous lines.* Since now weights represent areas, the geometrical proposition above stated has been proved to be a physical fact.

If you choose, you may reduce each weight to area, and find the ratio of areas instead of the ratios of weight.

EXERCISE V.

THE VOLUME OF SIMILAR POLYHEDRA IS PROPORTIONAL TO THE CUBES OF THEIR HOMOLOGOUS LINES.

This exercise may be conducted in precisely the same manner with wooden blocks, kept in a box. The simplest shape of the blocks is the right-angled tabular form.

EXERCISE VI.

TO DETERMINE THE RELATION BETWEEN THE AREA OR THE CIRCUMFERENCE OF A CIRCLE AND ITS RADIUS.

Models.—From homogeneous zinc or brass sheet, have, as accurately as possible, cut four to eight different circles, the radii of which range from 1 to 5 centimeters; also a rectangle of exactly 2 by 5 centimeters.

Student's work.—Weigh the latter; then exactly one-tenth of this weight is the weight of one square centimeter of the plate used. Call this weight c.

Enter this, together with the usual preliminaries, in your note book. Then construct a table like the the one in 46; mark the *vertical* columns (after the first) with the *number* designating the model. In the first column enter first line, r=radius. Measure the length of the radius of each plate carefully; enter the result at the proper place in the table. Multiply each radius by itself to form its square; enter these results below the former in the next horizontal line, which you mark r^2 (that is radius square).

Next determine the weight, w, of each plate; enter these values in the third horizontal, marked w. Then calculate and properly enter the area, a, of each circle; that is,—

$$a = \frac{w}{c}$$

Now calculate the ratios $\frac{a}{r}$ and $\frac{a}{r^2}$ for each circle; enter the results as before, in the next horizontal lines.

You will then find that the area divided by the square of the radius is for all circles very nearly the same, or a *constant quantity;* it is 3.14. Consequently you have—

$$\frac{a}{r^2} = 3.14,$$

or *the area* a *of any circle is obtained by multiplying the square* r^2 *of the radius by* 3.14. This constant ratio is termed *pee*, and usually denoted by the Greek letter π corresponding to the English p. That is, if $\pi = 3.14$—

$$a = \pi . r^2.$$

It is easily shown (if need be by the teacher) that the area a of the circle may be considered as composed of an immense number of small triangles, the base of each of which is a very short part of the circumference, C; while the height of all is equal to the radius. Hence we have $a = \frac{1}{2}$ C. r. Since also $a = \pi . r^2$, we have $\pi . r^2 = \frac{1}{2}$ C. r., and consequently—

$$C = 2\, \pi . r.$$

The circumference of any circle is $\pi = 3.14$ *multiplied by double the radius* (*i. e. the diameter*).

Note.—With glass balls of different sizes it is easy, in a like manner, to determine the volume v and the curved surface s of a globe. You will find—

$$v = \frac{4}{3}\, \pi . r^3. \qquad s = 4 . \pi . r^2.$$

How far do 46 and 47 cover the ground of 48?

EXERCISE VII.

IN ANY RIGHT-ANGLED TRIANGLE THE SQUARE OF THE HYPOTHENUSE IS EQUIVALENT TO THE SUM OF THE SQUARES OF THE TWO SIDES.

This famous and important proposition of pure geometry is readily established as a fact by any model prepared in the following manner:—

With a sharp point, draw any right-angled triangle on good, uniform sheet metal (zinc or brass.) Construct the square on each side, all *outside* the triangle. Cut out the figure very accurately.* Put the square of the hypothenuse on the one scale pan, the squares of the sides together on the other scale pan of a balance. You will find that there is equilibrium. Hence the above proposition is a fact.

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*This model in a strong envelop, is given to the student, who merely verifies the figure by putting the parts together. Then he passes to the balance.

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ELEMENTARY INTRODUCTION TO THE CHEMISTRY OF LIFE.

[Concluded from page 59.]

ANIMAL life, and fire, diminish the amount of oxygen in the atmosphere, while increasing the amount of carbon dioxide. Hence, in the lapse of time, the present conditions for life would greatly change.

This is the more apparent, since air containing as much as one per cent of carbon dioxide acts already deleterious on the human system. But as animal life has existed for ages on the globe without producing any dangerous accumulation of carbon dioxide in the air, there must exist a cause continually diminishing the amount of this gas in the air.

Vegetable life is this cause. Plants absorb carbon dioxide from the air, build their substance mainly from the carbon contained therein, and give up a great part of the oxygen to the atmosphere. This is proved by the following facts:—

1. Plants cannot grow in air completely deprived of carbon dioxide; for, brought into such an artificially prepared atmosphere, they die.

2. When a small, living branch with leaves is brought into a glass vessel containing atmospheric air, the amount of carbon dioxide in the latter diminishes, while the amount of oxygen increases, provided the plant be exposed to the sun-light.

Besides the carbon dioxide, plants take also water from the air, and part of the latter is found to combine with the carbon resulting from the former. The principal parts of plants, such as woody fibre, etc., is indeed composed of carbon, hydrogen, and oxygen, the latter two in such proportions as to be equivalent to carbon and water. Hence they are termed *carbohydrates.*

Decaying animal matter exerts a favorable influence on the growth of plants, constituting a ready source of nitrogen to the same.

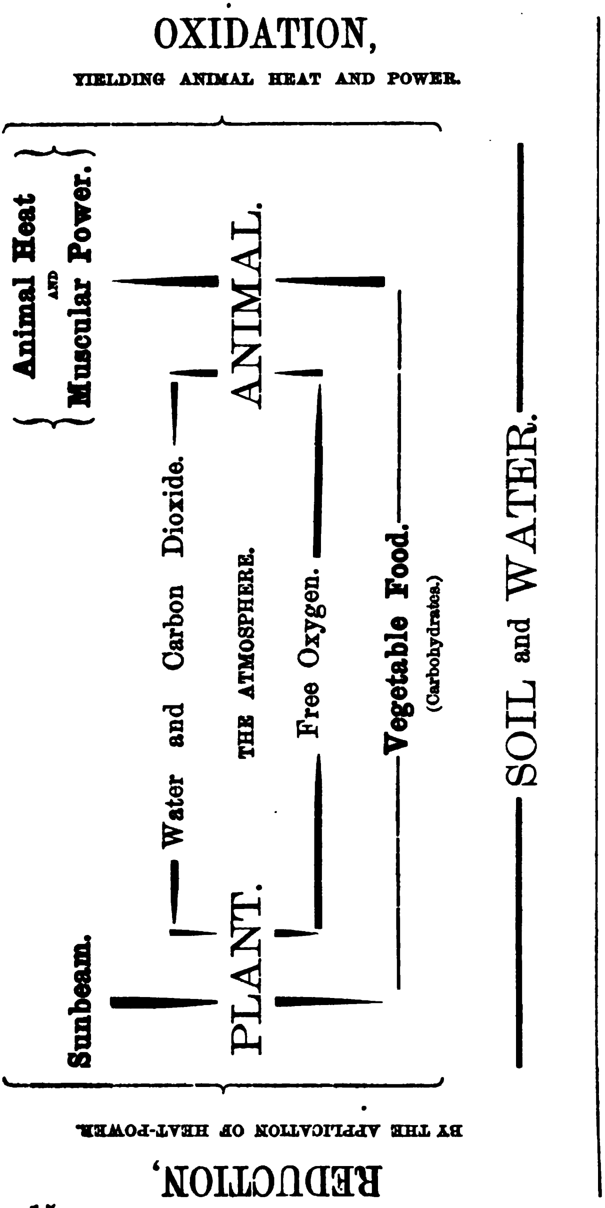
Finally, from the soil wherein the plant has its root, the plant obtains those mineral matters which constitute the *ashes* of the plant when burnt.

The *chemical life of plants* thus appears to consist mainly in the decomposition of the carbon dioxide taken from the atmosphere. The carbon is accumulated in the body of the plant, while the oxygen is returned to the air. But since carbon dioxide results from carbon and oxygen under production of a great amount of heat, heat must be applied to the carbon dioxide to separate the carbon from the oxygen. The life of plants, therefore, requires the expenditure of a great amount of heat or power to *reduce* the compound carbon-dioxide to carbon and free oxygen. This expenditure of heat is met by the sun's rays. Hence it is that plants grow only in the sunshine.

Since animals cannot live without plants, and since the plants require the power of the sumbeam in order to separate the oxygen from the carbon, we see that *the sunbeam is the true source of all physical life upon tne earth.*

Since, finally, the muscular power and the heat of animals, is due to the combustion of carbon and oxygen, both furnished them by the sun's action on the plant, the *life of animals*, both *in regard to heat and power, is a direct effect of the sunbeam*, being neither more nor less in amount, only changed in form.

The following chart gives a simple representation of the chemical process of life, or the *organic circulation of matter.* To better understand the subject, read the article once more carefully, while continually tracing the processes on this chart — just as you would on a map trace the journey of which you read the traveler's account: —


OXIDATION,
YIELDING ANIMAL HEAT AND POWER.
Animal Heat AND Muscular Power.
ANIMAL.
Water and Carbon Dioxide.
THE ATMOSPHERE.
Free Oxygen.
Vegetable Food.
(Carbohydrates.)
Sunbeam.
PLANT.
SOIL and WATER.
REDUCTION,
BY THE APPLICATION OF HEAT-POWER.

HINRICHS' CHART OF THE ORGANIC CIRCULATION OF MATTER.

THE AMERICAN CHEMIST. *A monthly journal of Theoretical, Analytical, and Technichal Chemistry.* Edited by *Chas. F. Chandler*, Ph. D. and *W. H. Chandler.* William Baldwin & Co., Publishers and Proprietors, 434 Broome street, New York. Subscription, $5 per annum, in advance.

For some years the *Chemical News*, edited by Wm. Crookes, of, and published at, London, has been re-printed in this country, the re-print being authorized by the editor. An " American Supplement " was soon attached to it, for the circulation in the United States. The *Chemical News* in many respects, deserves a wide circulation ; for it really is the only chemical journal of any note printed in the English language. The *Chemical News* appeared as a large quarto monthly, containing much original matter, and also *abstracts* from foreign (*i. e.* Continental) sources. The subscription was very low for such a paper ; *its circulation in the United States should have been immense ; for we possess thousands of High Schools and Colleges where Chemistry is (nominally) taught ; and what sane man would pretend to teach so progressive a science without at least taking and studying one such journal?*

But the circulation was not large enough ; the re-publication *has* been discontinued accordingly. What a testimony in regard to the condition of instruction in this great branch of science in our country ! A nation of forty millions — proud of our schools — and fail to sustain even a re-print !

We are glad to learn that the editor of the American Supplement, *Prof. C. F. Chandler*, of Columbia College, has not left the work in despair, but supplanted the *Chemical News*, of 64 pages, monthly, by the *American Chemist*, of 32 pages, monthly. We trust, indeed, then, this enterprise will not fail ; a *civilized* nation of forty millions should not be disgraced by so astounding a fact as would be the discontinuance of this, the *only* journal of chemistry in the United States!

Five numbers of the *American Chemist* are before us. They contain much that is valuable. *Every person* who pretends to teach chemistry in this country, should subscribe for this journal, even if he only *hears* classes in chemistry *recite* from some of the so-called text books of chemistry issued by enterprising New York houses*, and which are kept before the public for twenty and more years, because there is *capital* invested in them. For if each *teacher* only would subscribe to this journal, there is hope that in the course of a few years he would make the discovery that he has not yet taught chemistry at all,—has not studied it himself yet, *but is now feeling the necessity of commencing that study.* May, therefore, the *American Chemist* soon be received by each of these teachers; then we will, in a few years, be able to refer truthfully to the present condition of science in our schools without hurting so many persons' tender feelings, as we fear we do at present.

But the journal should also be taken by all who take an interest in the progressive work of science, the true civilizer of to-day. It should soon be understood that, however important an element our daily and weekly political press, it cannot, and is not by any one connected therewith, supposed to meet all the wants of intellectual readers, even if supplemented by our larger monthlies. For, although most papers now give stray notes on scientific topics, these notes are totally unscientific, forming scraps which are as destitute of the influence of the critical spirit of to-day as are the rhetorical beauties of *Pliny's* scientific encyclopedia.

From the first of January the *American Chemist* will become more independent of the the *Chemical News.* We hope it will then, also become more careful than the *Chemical News* in the *chemical notices* from foreign sources, which hitherto the *American Chemist* has reprinted from the *Chemical News.* For these notices evince that they have been compiled by gentlemen who are good, practical and experimental chemists, but almost totally ignorant in those branches of chemistry and physics which constitute molecular science. Thus, in the November nnmber, we are informed that C. Rammelsbery has found, for the crystal form of tin: "Its-form after fusion is, as far as can be ascertained, regular; but at a very low temperature this form is entirely modified, and belongs to the irregular system." It needs no further evidence to prove that the author of the notice containing this quotation has admitted to study even the very rudiments of crystallography.

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*For example, such scientific abominations as "Steele's Fourteen Weeks in (?) Chemistry."

In regard to all the important investigations in molecular science, the great field forming the neutral territory between the two principal branches of physical science (physics and chemistry), these notices are of the same calibre, except when they, as is very frequently the case, limit themselves to the very instructive form, elegantly expressed in some one of the following phrases: "A mathematico-physical essay;" "a mathematico-crystallographic essay;" "a crystallographical essay;" "a purely mathematico-mechanical essay;" "a lengthy physico-mathematical monograph on this *subject* not suited for abstraction," etc., *ad nauseam.*

The last *subject* was on the behavior of vapors as regards the law of Mariotte. Since now this law, applied by Ampere, has become the corner-stone of modern theoretical chemistry, it is peculiar to see so important a paper on this law thus snubbed. And, by the way, since when are papers, stating the results of a long course of original experimental or analytical research, called *essays?*

In conclusion, we most heartily and cordially recommend the *American Chemist* to the *American public.* We also hope that the able editor will, in the new volume of the *Amrican Chemist*, soon to begin, no longer admit such silly phrases of the *Chemcical News* as those above quoted under the title of "Chemical Notices from Foreign Sources."

THE AMERICAN ENTOMOLOGIST AND BOTANIST, edited by *Chas. V. Riley* and *Dr. Geo. Vasey*, and published by *R. P. Studley & Co.*, 221 Main street, St. Louis, at $2.00 per annum, will be suspended for one year.

We regret exceedingly to make this statement; for the above monthly has been of very high character — its illustrations were as fine as its text was excellent. It was not abstruse, but quite within the comprehension of those who have studied the rudiments of natural science, to which it was devoted. Besides, these branches are of fundamental importance to every intelligent farmer and horticulturist. Now, the Mississippi Valley is mainly inhabited by farmers and horticulturists. Why has so excellent a journal as the one in question not a circulation of at least 10,000 copies, but is compelled to suspend? Have we not the most excellent system of public schools? Are, in these excellent schools, the children of farmers not instructed in the first rudiments of botany? Do our excellent schools *willfully ignore nature*, in which we live and have our being? Is the system of public instruction, which we are told does constitute the pride of our country and the admiration of the world, limited to learning some few books by heart? Do our children in our schools only develop *one* of their mental faculties — that of memory?

We fear that the fate of our scientific journals answers these questions in a manner so serious as to call the earnest attention of all friends of education and progress to the facts involved!

Cornell's Physical Geography: Accompanied with 19 pages of maps, 130 diagrams and pictorial illustrations, and embracing a detailed description of the physical features of the United States. By S. S. Cornell, New York: D. Appleton & Company; 1870.

A very good specimen of the usual style of our so-called text-books in physical geography. It gives, therefore, an immense amount of detail for the unfortunate students to memorize. It is also admirably adapted for the Recitation Room; and it cultivates stupidity in teacher and student by having the customary set of questions at the bottom of the page.

Why does not Seth Thomas furnish as a clock, which in due succession brings to view first the question, then the answer? Such a clock would indeed meet with an immense sale; because, then, any one member of the class could *hear the recitation* of his colleagues; and the salaries now wasted upon teachers could be added to the sums so profitably spent for varnished school desks.

A text-book of the usual style for the pupils, and a set of dial-plates for the daily lessons in place of the teacher — and our system of instruction is nearly perfect.

O Seth Thomas, furnish us *that* clock!

A cheap microscope, of very elegant form, and quite sufficient for the student of most schools, we obtained from A. S. Aloe, optician, 206 North Fourth street, St. Louis, Mo., for $20, and have put it into the hands of our beginners in the laboratory. It is No. 118 in Aloe's Catalogue. We can recommend this little microscope to teachers.

THE DELAY in the appearance of this number is due to our being over-burdened with duties of the most different description. On no day does our regular school work occupy less than eight hours of our time.

We beg to excuse these delays, and think seriously to avoid them in the future — by reducing the *Monthly* to a *Quarterly*.

THE

American Scientific Monthly,

EDITED AND PUBLISHED BY

PROF. GUSTAVUS HINRICHS.

NOV. AND DEC. 1870.

IOWA CITY, IOWA:
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1870.

AMERICAN

SCIENTIFIC MONTHLY.

Edited and Published by Prof. Gustavus Hinrichs.

VOL. I. NOVEMBER AND DECEMBER, 1870. NOS. 5 & 6.

TO OUR READERS.

IN our prospectus, printed on the cover of the first two numbers of this Journal, we said:—

"This new Journal appears on the first of each month. Each number contains thirty-two finely printed octavo pages, and treats of the following:—

1. Popular or General Science, with especial regard to the daily increasing practical and social influence of science.
2. Science for Schools, giving not only general articles on this subject, but also special information on new apparatus and materials, improved methods of teaching, with outlines of model lessons for teachers in the common and high schools.
3. Reviews of new scientific books.
4. Biographical sketches and notes on eminent scientists.
5. Descriptions of scientific establishments, such as chemical laboratories, astronomical observatories, botanical and zoölogical gardens, etc.
6. Original contributions to science.

"Eminent men, in the several branches of science have promised to communicate articles to the different departments of this Journal; besides, some of the best articles appearing in English, German, and French scientific journals will be frequently presented to the readers of this Monthly.

"Every number will accordingly contain something to interest the general reader, the business man, the school-teacher, the student in college, and the original investigator.

"The editor hopes that the SCIENTIFIC MONTHLY will secure a sufficient number of subscribers and friends during the remaining six months of the present year (for which time he guarrantees the regular appearance of the Journal) to warrant its enlargement at the beginning of next year, and the regular introduction of illustrations and plates.

"The active coöperation of all who are interested in the cause of science and education is earnestly desired, especially in order to increase the circulation of this Monthly.

"A limited number of advertisements of scientific books, periodicals, materials, apparatus, schools, &c., will be inserted."

The six months for which the appearance of the MONTHLY was guaranteed by the Editor have passed. With the exception of the *prompt* appearance on the first of each month, we believe to have faithfully fulfilled our promises. These *delays* have never been caused by any lack of energy on our part; the printing of the MONTHLY at a distance from our place of residence has often quite materially increased these delays, especially in regard to this last number. A glance at the contents of this double number will readily show why.

A glance at the table of *Contents*, printed on another page, will, we trust, testify creditably to the variety and permanent value of the articles contained in the MONTHLY.

When, some three months ago, we looked at the table of contents as it was, and compared it to our promises in the prospectus, we found that all but the last (6th) branch of the MONTHLY had received the proper attention. To redeem our promise, we have devoted much of the last number to this subject of *Original Contributions* to Science. But in order to be of value at least to our student subscribers, we have written a very concise synopsis of the acquired knowledge to which these contributions were added. In this way resulted a *Synopsis of Pure Crystallography*, embraced in this number. No such synopsis can be found in English; therefore we deemed it advisable to make it independent from the MONTHLY in *form.*

While we thus have tried to redeem our promises, we have not been cheered by the realization of our modest hopes. It is true, we have secured subscribers enough to warrant the continuation of the Journal in the hands of a publishing firm able to lose something for a year or two, in anticipation of establishing a Journal; and therefore we ought, perhaps, to be satisfied, especially since we have not advertised our MONTHLY directly. Still our subscription list is not large enough to allow *us* to continue the MONTHLY; the same will therefore close with the present double number.

But we cannot close without thanking all those who by their subscription have assisted us in what we consider a laudable enterprise. We also sincerely thank the *Editors of the political papers of Iowa* for friendly notices of this enterprise as well as for the exchanges which they have favored us with. Finally we feel deeply grateful for the encouragement given us by the scientific press both in this country and abroad, and we regret that our space has been too limited to permit us to acknowledge and reciprocate the many courtesies received.

SCIENCE IN VIENNA.

VIENNA is renowned for great scientific activity. Not only does it contain great schools, especially the University and the Polytechicum, wherein every branch of science is taught by men who are thoroughly at home in what they teach; but it also contains many scientific societies, which in public meetings present to the world the new discoveries made by their members, or others, and by their often considerable pecuniary means are enabled to publish these discoveries and researches in volumes, which, in regard to contents and form, are the admiration of scientific men throughout the world.

Strange enough, none of these scientific societies are more than than twenty-five years old. Before the year 1845, no society devoted to the culture of science for its own sake, existed in the old imperial city. But the essential elements of such societies did exist there in men who arduously devoted themselves to the service of science.

Foremost among these men, was Wilhelm Haidinger, then the faithful successor of Mohs, now the Nestor of crystallographers. By a liberal and cheerful recognition of every point of serious research, by suggestive advice, and ever ready assistance, he drew to him numerous investigators, who now have gained a well-earned reputation, and who, in whatever country they reside, continue to cherish the name of their ever active teacher and friend.

On the 8th of November, 1845, some of these men met at the mineralogical museum, directed by Haidinger, and constituted themselves as a society of "The Friends of the Sciences of Nature in Vienna"—*Die Freunde der Naturwissenschaften in Wien.*

By means of voluntary subscriptions, enough money was raised to commence the publication of "*Reports*" and "*Transactions*,"—the latter in grand quarto are really admirable. All of this was done through the personal labor of these friends. These publications continued until 1851, when the friends disbanded, because two more stable, more promising centres of action had been created; these centres are the Academy of Sciences and the Geological Institute.

The Imperial Academy of Sciences of Vienna was created May, 1846, and held its first meeting December, 2, 1847. Created by imperial munificence and fostered by an enlightened government, it stands unrivalled among the academies of the world. Its publications, issued from the renowned Austrian government press, are really splendid, and the form but harmonizes with the contents. Professor Schroetter, known to a wider circle by the discovery and exhaustive investigation of red phosphorus, is the secretary of this body.

The Geological Institute of the Empire, was founded in November, 1849, and will forever remain the great monument of Haidinger, who planned it and guided it until in 1866, when brain fever for a time prostrated the ever active investigator. His friend, and for many years his colleague, Franz v. Hauer, worthily succeeded the founder in the direction of this vast institute. We can not, at present, attempt a description of this Institute, but must defer it to some future time. Besides these two scientific institutions, Vienna now contains fourteen other scientific bodies, each one devoted to the development of some special branch of science. Of these, the following are particularly important: The Zoölogico-Botanical Society, founded 1851, the Central Institute of Meteorology and Magnetism (1855) and the Society for the Diffusion of Science.

Well may the people of Austria feel proud of the grand results attained by these institutions which they so liberally support; and well may those who untiringly worked for these results, look with satisfaction back upon so blessed a past; but even to us, in a new country and under conditions very unfavorable to the steady cultivation of science, there is a lesson in the rapid development and successful organization of science at Vienna. For we learn that this success resulted from a happy union of devotion to science in the few active laborers, appreciation of science by the many, and liberality towards science by those who rule.

In a democratic country this union cannot be brought about until our schools have given a fair place to science; until then we are condemned to stand back and admire what is done elsewhere.

◆

FRENCH HISTORY OF SCIENCE.

[From the Moniteur — received by balloon.*]

A FEW years ago, Wurtz, a French chemist, published a history of chemistry. He commenced, as a true Frenchman, thus: —

Chemistry is a FRENCH *science.*

The assertion, which in modesty and accuracy reflects both the erudition and equity of the French, and in its high regard of historic truth is only paralleled by the proclamations of our great barrister, Gambetta, has never yet been contradicted by any French chemist. It was, however, quite speedily denounced by Crookes, and other equally illiterate English scientists; they were inclined to suggest and dared to say that some of their countrymen, such as Cavendish, Black, Priestley, Watts, Dalton, Wollaston, Davy, and Faraday, possibly might be considered as chemists as well as — Lavoisier, who had the very remarkable misfortune of publishing *his* original discoveries in *French*, and at the centre of the world, *Paris*, only

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*Our readers will perhaps be astonished to learn that the statements in this parody are essentially *historical;* the facts mentioned are familiar to those who read the journals. We think the synopsis given by the French *Moniteur* quite reliable, therefore we translate the same.—[Ed. Am. Sc. M.

after the same discoveries had been published in that barbarous *English* language which no Frenchman needs to know, and at the out-of-the-way hamlet termed *London.* No Russian ever told these stupid English that they by opinions so at variance with French self-respect, did introduce into science an element foreign to science; no Russian ever contradicted Wurtz's statement either — for sure enough, chemistry is *not* a Russian science, but a *French* science.

But — ignorance will display. Some time early last summer, when France so truthfully told the world that "peace" was her only aim — a certain Woll-Hart, one of those barbarians living in a country adjacent to the North Pole,* and styling himself professor of *chemistry* (*sic*) in the village of Munich,† attempts to prove by a few German sentences, clear as water, and as impassionately — cold as the icicle which forms the axle‡ of the earth, that our French Lavoisier cannot be honored for the foundation of chemistry, as asserted by the French author, Wurtz, because Lavoisier evidently was no chemist at all. Soon after, a certain other Teuton, by the name of Kol-Be, pretending to be director of a chemical laboratory in the seaport Lipzic, on the Caspian sea,¶ wrote in a journal which he evidently believes read by some people, that the French had no real chemical laboratories, like those found in Germany; he said that the French had no laboratory like that of the promising young chemist, Aw. Hop-Mann, in Berlin,† who invented the new boot-blacking, made of aniline, and also first established the fact, that a donkey soaked in sulphuric acid turns into the parchments so extensively used in France for collegiate diplomas. Besides this Kol-Be rather intimated that the thing which is called his laboratory is superior to any laboratory in France.

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*According to French geography.

†A cold place near the Baltic; the people eat sausages in winter and drink beer in summer.

‡During the cold of winter the axle is strong and smooth, and the earth revolves with comparative ease; hence the days are short. But in summer the axle thaws off, and the roughness resulting increases the time of day.—Compare Aristotle and other French classics.

¶We faithfully and exclusively follow our *French* sources. Hence, if any of the readers should think that Lipzic is not on the Caspian sea, but on Lake Superior, they will acknowledge themselves in error.—[EDITOR'S REMARK.

Immediately upon the receipt of these astounding insinuations of the barbarous Teutons, the four chemists of All Russia met in solemn council at Peterboro, and passed the following resolutions, a copy of which was sent to Paris by the pigeon recently eaten at the banquet of Trochu:—

WHEREAS, It is true that the French chemist, Wurtz, knowingly and wittingly stated an absurd falsehood; and

WHEREAS, The English chemist, Crookes has long ago established this fact as such, be it hereby

Resolved, That we condemn the Germans, Woll-Hart and Kol-Be for having dared to more fully prove the first whereas; and also

Resolved, That the German barbarians have lost the sympathy of the civilized world, especially that of the Cossacks and the Tschuktschen, because said barbarians did not sufficiently appreciate the high honor of having their country overrun by the nation which marches at the head of civilization, with armed Zouaves from the galleys, and roaming Turcos from the neighborhood of Sahara; and, finally,

Resolved, That the Germans are brutes, not able to understand the civil and peaceful greeting spoken to them by chassepot and mitrailleuse.

It was further resolved, that the Peterboro *News* publish the above resolutions, as well as the argument on which they clearly rest. While we do not think the phraseology very euphoneous, we still take pleasure to publish the above resolutions, because it shows that the Four Chemists of Russia agree with our Wurtz.

JEAN DE FRANCE.

---

†Now noted as the residence of William Barbarossa, who formerly slept a great deal in the town Kiff-Heiser.

THE PRINCIPLES

OF

PURE CRYSTALLOGRAPHY;

A LECTURE-GUIDE,

BY

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MEMBER, OR CORRESPONDENT, OF SCIENTIFIC SOCIETIES AT
BERLIN, VIENNA, KŒNIGSBERG, EMDEN, ETC.

DAVENPORT, IOWA, U. S.
GRIGGS, WATSON, & DAY, PUBLISHERS.
LEIPZIG: F. A. BROCKHAUS.
1871.

PREFACE.

These few pages are intended both for students and for investigators.

To my *students* these pages will constitute a guide to the course of lectures on pure crystallography, delivered each fall term (September to December), at the Chemical Laboratory of the State University of Iowa. For their use it may be bound up with enough blank paper to enter diagrams and notes taken at the lectures, so that they have the whole subject in one volume.

To the *investigator* the author offers these pages as an excuse for the English edition of Atomechanics promised two years ago, particularly since demands for that work have recently become more frequent again, especially from Germany. The reader will, in chapters V. and VI., find a concise exposition of the present status of Atomechanics in relation to crystallography.

Our treatise on the so-called crystal-systems, especially the quadratic, hexagonal, and tesseral forms, is herein offered to the careful consideration of all crystallographers. We have united the opposing views of *Schrauf* and the older crystallographers, and trust that, also, here the mean may approach truth more than either of the separate determinations. See articles 48 to 60, and 80 to 100.

Our crystallographic notatation (see 11, 62, 64, 67), will perhaps be found to unite the simplicity of the notation of Miller, with the directness of the notation of Weiss. Why we cannot use Miller's may be seen from 147 to 150.

Some years ago we sought recreation in the study of Chinese. In the fourth book of *Lun-Gnee*, we found (I. 8), a few words which the younger readers of this synopsis may often have occasion to think of while studying these pages. We therefore quote *Chee:* "Who do not strive to learn, to them I do not unfold my Ideas; who open not their minds, those I do not labor to instruct. When I describe one corner, if the pupil comprehend not the other three, I do not repeat my instructions."

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CRYSTALLOGRAPHY.

CHAPTER I.

Crystal Elements.

1. A CRYSTAL *is a polyhedron formed spontaneously by its own particles.*

CRYSTALLOGRAPHY *is that branch of physical science which treats of the form of crystals.*

These definitions are deduced from observations on cryssallization and crystals in HINRICHS' ELEMENTS OF PHYSICS* Chapter III., Section V. and VI, where also the other necessary definitions here used occur. Only after having carefully worked his way through these two sections—or their equivalent—can the student successfully master the present very concise treatise of pure crystallography. At the same time it is essential that the student should be *practically* familiar with Section VI. of Chapter I. of the same work, and especially with Articles 71 to 80, treating of co-ordinates in the plane and in space.

2. Any two *zones* of a crystal will determine three *axes*, X, Y, Z, (Physics, 199). The three *axial-planes*, X

---

*For the sake of brevity we shall refer to the above work as PHYSICS and give the number of the article referred to. Thus Physics, 199, means article 199 in the above work.

Y, Y Z, Z X need only be laid parallel to three different crystal faces, such as P, M, T, (Physics, 168, 169). In this case X would be the axis of zone P M, Y of zone P T, and Z of zone M T. Faces P, M, T, are called *pinacoids*, if they are parallel to the axial planes.

3. The crystal is usually placed in such a position that the *third* axis Z is *vertical* (Physics, 80). The *first* or *proto-axis* X is directed from the center O towards the right of the observer.

4. The magnitude of the *inter-axial angles* evidently depends upon the crystal described (Physics, 173,) and upon the faces selected on this crystal. (2.) However, the faces are usually selected so as to *make the axial angles as nearly right angles as possible.*

These inter-axial angles are denoted by letter α, β, λ, namely the rotation around by

X Y Z

α – y z; β – x z; γ – xy.

5. Accordingly we have the following four possible cases:

1°. *None* of these angles is exactly 90°; or $\alpha \gtreqless \beta \gtreqless \gamma \gtreqless 90°$. Such crystals are termed *triclinic.*

2°. Only *one* of the interaxial angles is exactly 90°; $\alpha \gtreqless \beta \gtreqless \gamma = 90°$. Such crystals are termed *diclinic.*

3°. Two of the interaxial angles are exactly 90.° $\alpha \gtreqless \beta = \gamma = 90°$. Such crystals are termed *monoclinic.*

4°. Finally *all three* of the interfacial angles may be exactly 90°; that is, $\alpha = \beta = \gamma = 90°$. Such crystals we term *orthoclinic.*

6. Besides the three pinacoids used for the determination of the axial planes (see 2) a crystal has at least one more face, F, intersecting the above three faces, and therefor also intersecting the three axes. The lengths cut off on the axes by this face F we term the *fundamental axes* of the crystal, and denote them by the letters a, b, c. The face F is also called the *fundamental face* of the crystal.

7. If the crystal possesses many faces besides the three pinacoids, any of the three faces *may* be selected as the fundamental; but we shall see that in many cases some one of all three faces is distinguished from all others of the same crystal by certain important properties, which show that face to be *the* fundamental one of the crystal.

8. The *magnitude* of the three angles α, β, and , and the *length* of the three fundamental axes a, b, c, constitute the six ELEMENTS *of a crystal.* Since, however, the angles only of crystals are of importance, and not the absolute linear dimensions, (*Steno's Law*, Physics, 173,) we can always put one of the fundamental axes equal to unity. We select usually $b = 1$.

9. Any other face f of a crystal will be completely determined by the three *parameters* x, y, z, cut off by the face from the three axes X, Y, Z

10. Observation has proved that the parameters x, y, z of any crystal face f stand in a simple, *rational* ratio to the fundamental axes a, b, c; that is, to the parameters of the fundamental face F. Consequently:

$$\frac{x}{a} : \frac{y}{b} : \frac{z}{c} = h : k : l.$$

The letters h, k, l are accordingly *simple*, *entire numbers*, and we may put the parameters

$$x = h.\,a. \qquad y = k.\,b. \qquad z = l.\,c.$$

11. The simple, whole numbers h, k, l, are termed the *indices* of the face f, and when written one after another *in the order* hkl, constitute the *formula* of the *face* f. The *first* index corresponds always to X, the *second* to Y, the *third* to Z. Thus 235 is the formula of a face intersecting the first axis (X) at a distance 2 a, the second axis (Y) at a distance 3 b, and the third axis (Z) at a distance 5 c. The *parameters* of this face are 2a, 3b, and 5c; the indices are 2, 3 and 5.

Hence, also, the formula of the fundamental F is 111.

12. If the face f intersects any of the negative axes, the corresponding parameter, and therefore also the corresponding index becomes negative. For the sake of brevity the *minus* sign is written *above* and not before the index. Thus
$\bar{2}35$ is a face, which intersects the X axis at the distance —2a or 2a to the *left* of the origin O. (Physics, 80 and 71.)

13. *The law of simple rational indices* (10) distinguishes a crystal from any artificial polyhedron. On some crystals many hundred of separate faces have been observed, (compare Chapter IV.;) but they are all *accurately* represented by simple whole numbers h k l. The most frequent values of these indices are 1, 2, 3; also infinity, if the face be parallel to some axis.

14. A face hkl intersects all three axes X, Y, Z, unless one or two of the indices is infinite. Faces intersecting all three axes are termed *pyramidal* faces. Thus hkl 2 3 5, 1 2 1 are pyramidal faces.

If, however, the face is parallel to an axis it is called a *prismatic face*, and the corresponding index is infinity. Thus $hk\infty$, $h\infty l$, ∞kl are prismatic faces. The last two faces, parallel to the not vertical X or Y, are called *domatic* faces.

If, finally, the face is parallel to two axes, it has both the corresponding indices infinite, and is termed a *pinacoid.* Thus $1\infty\infty$ is the *deutero-pinacoid*, parallel to the axial-plane Y Z; $\infty 1 \infty$ is the *proto-pinacoid*, parallel to the axial-plane X Z, and $\infty\infty 1$ is the *basal pinacoid* parallel to X Y.

15. *A simple form is composed of all those faces f which possess the same numerical indices h k l, although of different sign, provided the faces have the same inclination to the three axes.* The *formula* of such a simple form is (hkl) the bracket (— – —) indicating that *all possible changes in sign* are to be made, consistent with the preservation of the inclination to the axes.

16. Crystal forms, composed of more than the faces of one simple form, are termed *combinations* of the several simple forms composing the same. Thus a crystal bounded by the forms (123) (111) (157) (132) (113) etc., would be a *combination* of these forms.

17. In the description of such combinations it should always be stated which simple form or forms *dominate.* This, together with the formula of the component forms constitutes the *habitus* of the crystal (Physics, 172).

18. Often crystal faces exhibit certain peculiarities; but usually *all the faces of the same simple form possess the same peculiarities.* Such facts are intimately connected with the formal habitus, and should be mentioned in connection therewith.

19. *An interfacial angle* is denoted by writing the symbols of the two faces in succession. Thus 235 : $2\bar{3}5$ is the interfacial angle between face 235 and face $2\bar{3}5$.

Accurate measurements of such interfacial angles should be recorded with the description of the crystal.

20. It is easily seen that the interfacial angles are determined theoretically by the *elements* of the crystal and the *indices* of the faces; but the values of interfacial angles thus determined are distinguised as *calculated* from those obtained by direct measurement.

21. These calculations require the use of spherical trigonometry. It is, however, quite sufficient for beginners to determine some of the most important angles by *construction* from the elements, by the methods of linear drawing, given in Physics, 51—80. It is especially important and very easy to construct the angles in the three axial zones, in orthoclinic crystals.

22. The *elements of a crystal* are obtained from the observed angles by like method of calculation or construction. Thus in orthoclinic crystals the elements are determined by means of two zones, such as the vertical parallel to the axis Z, and the horizontal parallel to the axis Y or to X. In potassium nitrate (Physics, 181) the zone Mb gives, by the angle MM' the ratio a: b, while the zone Dd b will, by the angle b D, give the ratio a: c, so a: b: c are determined. Besides $\alpha=\beta=\gamma=90.°$ Practice!

23. Having determined the elements, it remains to determine the *indices* for the observed faces. This may again be accomplished by calculation or, in the simple cases, by construction. Thus, in the above case, we have evidently determined the elements by the faces M and D of nitre, so that M is 11 ∞ and D is 1∞1. If in the zone Ddb also face d is drawn, according to its observed inclination (Physics, 181) it will be found that d is 1∞2. Also that b is 1 ∞ ∞.

The crystal descriptions in *Physics* 182, 183, 184 may be used in the same manner for the determination of the elements of these crystals.

24. *Four faces are sufficient to determine the elements of any crystal.* Three faces will determine the interaxial angles α, β, γ, (see 2 and 4;) while the fourth face may be taken as the fundamental F (see 6). In order that this latter can be fixed in position towards the former three the inclinations of F with any two of the former are required. Hence the total number of *angles* sufficient to determine the elements of a crystal is *five.*

25. But it is well to take more than this least possible number of angles into account, in order, as far as possible to determine the unavoidable *errors of observation* and the slight *irregularities* which crystals at times exhibit.

The best method consists in calculating the elements from any five observed angles. Then by comparison with the observed angles the *errors* can be obtained.

Now change the elements to a slight extent, and repeat all calculations. A new set of errors will thus be obtained.

Since very small changes in any two variables always are nearly proportional, data have now been obtained for the determination of *that* change in the elements which would reduce all the errors, as nearly as possible to zero. (*Von Lang*, Krystallographie, Wien, 1866, p. 351—352.) For applications see *Von Zepharowich*, Krystallographische Studien über den Idokras, Wiener Sitzungsber. 1864, Bd. 49. Abthl. I., p. 21—24.

The method of least squares has been used for this purpose, in a less elegant manner, by *Schabus* 1855; also, for the angles of pyroxene, by *von Kokscharow*, Materialien zur Mineralogie Russlands, Bd. IV., pp. 370—385.

CHAPTER II.

Crystal Drawings.

26. The common *Crystal drawings* are either horizontal, vertical or oblique projections of the crystal. See Physics, 75. A very good representation is obtained by the common oblique projection together with a horizontal projection of the same crystal. In this manner crystal forms are figured in the excellent *Atlas* accompanying *Von Kokscharow's* Materialien zur Mineralogie Russlands.

27. The most common *oblique* projection used exhibits the crystal's front turned about 18° to the observer's left, and the crystal's top turned about 6° down towards the observer. The first angle is termed the angle of declination, the last the angle of elevation.

Otherwise the oblique projection is *axonometric;* the rate being very nearly along X and Z full scale, but along Y *one-third* full scale. See Physics, 76. First the elements are constructed, then the faces are entered by their indices. Practice!

28. Besides these crystal drawings two indirect methods of representing crystal forms on paper have proved very useful; they are the so-called *methods of projection of Quenstedt* and *Miller*, which, however, are both developements of a method first proposed by *Neumann.* Large projections of this kind (for b one or several dm) I find very useful in the lecture room.

29. *Quenstedt's Projection is a linear projection.* It is obtained on plane a b by intersection of *projection planes* laid through the extremity of the axis c, and parallel to the crystal faces themselves.

30. Accordingly *each face will be represented by a line* called the *trace* of the face. Only the basal face cannot be represented in this projection, because it does not intersect the plane a b. The trace of any face parallel to the vertical axis c passes of course through the point of intersection O of the axes a and b; that is the faces h k ∞ have traces passing through O, and parallel to a line cutting off the indices h and k on a and b.

All other faces have traces of the indices μ and ν or a and b in the projection, determined by

$$\mu = \frac{h}{l} \qquad \nu = \frac{k}{l}$$

31. Since all the edges of any one zone are mutually parallel, these edges are all projected in the same point, which is called the *zone-point. The traces of all the individual faces of the zone pass through this zone-point;* for the projection plane of each face also contains the common projection-line of the edges.

The point of intersection O of the axes a and b is thus the zone point of the zone parallel to axis c. See 30.

32. It is easy by direct observation to ascertain whether any given face f belongs to a given zone; for we need only to rotate the crystal around the axis of the zone so that the light is successively reflected from the different faces of the zone to our eye—if the face f also in its turn reflects the light to our eye, it is in the same zone with the other faces in question.

33. If now a face f is thus found to belong to *two dif-*

ferent zones, the zone-points p and p′ which are known in the projection, we can draw the trace of the face f in the projection; for it is the straight line passing through the points p and p′. Hence also the indices μ and ν will be determined, and therefore also the full formula h k l of the face (see 30.) This is the *deduction* of the face.

34. Thus the mere observation of the *zonal relations* of a face very often suffices to accurately determine its formula without any calculations whatever. Herein consists the principal practical importance of *Quenstedt's* projection. Practice the same on some of the crystals studied. Especially Physics, 181 to 183.

35. If carried out in the usual way, by full lines, the projection becomes often an intricate net-work of lines. I therefore draw the trace full only *between* the two axes it intersects, or near the centre of the figure, and *faintly dot* the continuation of the trace. In this manner the projection also brings out the symmetry of the crystals, and becomes really elegant.

36. I also add the vertical projection of the extremity of c, through which all projecting planes are laid, and somewhere near the margin of the drawing mark the *length* of that axis c (to scale.) Only in this way is it easy to obtain at any time immediately a *correct* view of the crystal form, especially in case of triclinic and monoclinic forms.

37. In *Miller's Stereographic Projection* a sphere is described around the center of the crystal, and each face F moved parallel to itself until it touches the surface of this sphere; this point is called the *normal point*, n, because the radius to this point is normal to the crystal face.

The plane of projection (the paper) is usually passed through the axial plane a b; at times, however, at right angles to c. This plane of projection will intersect the sphere in a circle which is drawn on the paper and termed the *circle of projection*. From the center of this circle a perpendicular is drawn down until it intersects the spherical surface below in a point termed the *nadir*, N.

The nadir N is joined by a straight line with the normal point n of the face F. The point p where the line of projection Nn intersects the place of projection, (the paper) constitutes the *projection* of the normal point, and thus the projection of the face F.

38. It is evident, that each face F will thus be accurately determined in position by its projection p; and also that the entire projection will fall in, or inside, the circumference of the circle of projection.

It is also readily seen, that the zone at right angles to the plane of projection is projected in the circle of projection.

Since the normal points n of any zone are in a plane passing through the center of the sphere, they are in a great circle on the sphere; and therefore will also form an arc of a circle in the projection. Hence it is also quite easy in this projection to trace up the faces belonging to any zone.

39. The angle between the radii of the sphere drawn to different normal points n, projected in the points p, can easily be determined by very simple construction, at least if the points p are in a known zone. But this angle is evidently the angle between the normals of the two faces, or the *inter-normal angle*, n.

40. It is easily seen that the inter-normal angle is the supplement of the *interfacial angle* f; or $n+f=180°$. Hence we may, according to circumstances, either determine the internormal or the interfacial angle between any two faces in the crystal. By means of *Haidinger's* method (Physics, 171) both of these angles are observed with equal facility. By the application goniometer we obtain the interfacial (see Physics, 170). But by the more accurate *reflecting goniometers** we read off the internormal angle direct; hence these are of late more frequently given in crystal descriptions, than the interfacial angles.

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*The reflecting goniometer of von Zepharowich in Prague enables him to determine the angles to within five seconds exact! See Wiener Berichte, 1861; Bd. 43, Abth. 2, p. 547.

For a crystal face 2 mm long this is within 0.00005 mm of linear extension.

Always be careful to ascertain which of these angles are referred to in crystal descriptions!

CHAPTER III.

Crystal Forms.

41. THE SYSTEMATIC DESCRIPTION OF A CRYSTAL may now be understood. Such descriptions are best given in the following order.

1. *The elements.* See 8 and 22.

2. *The simple forms observed.* See 15. Giving the *letter* used to denote the faces, and also the formula of these faces. In this enumeration it is not always necessary to write the brackets.

In this enumeration it is essential to distinguish between the full and partial forms, more completely characterized below as *holohedral* and *hemihedral* forms. *Twin* forms should also be enumerated. See 61.

3. The enumeration of observed forms should be accompanied by a *projection* representing all the faces observed, either according to *Miller* (37) or by our modified form (35 and 36) of *Quenstedt's* projection (29).

4. The *habitus* (Physics, 172) of the crystals should next be fully given, as far as possible in reference to methods of crystallization for artificial, and to locality and occurrence for native crystals. Also the *peculiarities of the faces* of simple forms (18) should be described, such as their *striations*, etc. Compare 17.

5. In this connection some of the most important of the *physical properties* of the crystal, varying with the faces, should be given, especially the *cleavage.* See Physics, 197).

6. The *calculated* values of the interfacial or internormal angles should be tabulated, and

7. These *calculated angles should be critically compared with the observed values*, thereby finally leading to

8. A discussion of the *influence of composition and external circumstances on the elements* or the crystal form. It will then appear, that the elements α, β, γ and a, b, c, are *not* constants, but *functious* of atomic weight, temperature, and other variables.

42. A crystal-form having all faces in parallel pairs is *holohedral* (Physics, 169). If no two faces on a form are parallel the form is *hemihedral.*

For any face hkl the holohedral form therefore also contains $\overline{hkl}$ while the hemihedral forms do not contain the face $\overline{hkl}$.

43. If all faces possible according to the degree of symmetry of the elements are present in a simple holohedral form, the latter is *holosymmetric;* if only half the number are present the form is *hemisymmetric.*

The same terms are used for hemihedral forms.

44. In a *triclinic crystal* (5) *the simple form* (*hkl*) *consists of the two parallel faces only.* For a change in sign in any of these indices produces a change in inclination to the axes in the corresponding face. Consequently no really hemihedral forms are possible in a triclinic crystal.

The *diclinic* forms agree in number of faces with the triclinic crystals.

45 *The monoclinic crystal* (5) has simple forms composed of *four* faces. For hkl and $\bar{h}kl$ are equally inclined to all axes, because X is at right angles to both Y and Z. They form an inclined zone. The two faces parallel to these increase the number to four in the simple form of monoclinic crystals.

46. *In the orthoclinic crystals* the four faces p=hkl, q=$\bar{h}kl$, r=$\overline{hk}l$, s=$h\bar{k}l$ have the same inclination to the three axes; they form a *four sided rhombic pyramid* around the *upper* half (l positive) of the vertical axis.

Their parallel faces p′ q′ r′ s′ (l negative) give an equal rhombic pyramid below, so that the *holohedral* simple form (h k l) of an orthoclinic crystal is a double four-sided rhombic pyramid; we shall, for the sake of brevity, term it an *octaid*, because it is bounded by *eight* equal triangles.

47. If the axes of the octaid are all different, then the octaid is the holohedral form. Such orthoclinic crystals are termed *rhombic*, because the three axial sections are rhombs.

48. If, however, two axes are exactly equal, then each octaid (hkl) must occur in two positions, of which one results from the other by a rotation of 90° around the third axis. Such crystals are termed *quadratic*.

The holohedral simple *quadratic* form is a double eight sided pyramid of 16 faces, called *dioctaid*, and represented by the formula

$$[hkl]=(hkl)\ (0^\circ+90^\circ)$$

where the octaid (hkl) is indicated to be taken for Y in the direction of axis b and *also* for Y in the direction of axis $\bar{a}$, at 90° from the former The brace [ ] is used here and in the subsequent to indicate the combination of the orthoclinic octaid (46) in the different positions determined by the degree of *rotary symmetry* peculiar to the crystal. The vertical axis c is the axis of rotary symmetry, also termed the principal axis.

49. If the orthoclinic octaid (46) has the axes $a : b = \sqrt{3} : 1 = 1.73205 : 1$, the axial section *ab* is a rhombus of *exactly* 120°, which implies the *regular hexagon*. In this we have three equal diameters, mutually distant by 120°.

Hence the octaid in this case must be repeated 3 times, with the axis Y at 0°, at 120° and at 240°. Consequently the holohedral simple hexagonal form is a *tri-octaid*, or a double twelve-sided pyramid of 24 faces, called the *di-hexagonal pyramid*. It is represented by

$$[hkl] = (hkl)\,(0^\circ+120^\circ+240^\circ).$$

50. If in a quadratic crystal (48) the third axis c becomes equal to the axis $a=b$, then also a and b become axes of the same degree of rotary symmetry, which c possesses in the quadratic crystals. Hence we have for *each* axis a, b, c such a diquadratic pyramid, and the holohedral simple form has 48, or three times the number 16 of faces which it has in the quadratic crystal. The formula of this form is evidently

$$[h\,k\,l]=\left\{\begin{array}{l}(hkl)\ (0^\circ+90^\circ)\\ +\,(hlk)\ (0^\circ+90^\circ)\\ +\,(lhk)\ (0^\circ+90^\circ)\end{array}\right.$$

if l is the index on the axis around which the rotation of 90° takes place. This form is a *triakis dioctaid*, but it is usually called the *Hexakisoctahedron*, because it is bounded by six-times-eight or 48 faces. *Haidinger* has called it the *Adamantoid*, because it has been observed on the diamond.

Crystals, wherein $a=b=c$ are termed *quadrotesseral*, because for $h=k=\infty$ the simple from $[hkl]$ becomes $[\infty\,\infty\,1]$ which is the cube or tessera, also called *hexahedron*.

51. In the hexagonal crystal (49) the vertical axis c may, of course, have any value. But if $c=\sqrt{2}=1.41421$ the hexagonal form $[\infty\,11]$ consists of two cubes* $^{\pi}[\infty\,11]$ and $^{\pi}\infty\,\bar{1}1]$ turned 180° against one another around a diagonal as the vertical axis of rotation. These forms we term *rhombo-tesseral.*

52. Mathematically the quadro-tesseral forms are identical with the rhombo-tesseral forms, but changed in position. Hence they are, by probably all crystallographers, referred to as *tesseral* forms without distinction.

We shall soon see that these forms are physically, and therefore crystallographically, very different from one another. Compare 99, 100.

53. We have now learned to distinguish the following six crystal forms, the elements of which successively specify to simpler values, while at the same time the holohedral form attains to a constantly greater number of faces expressive of the increasing *degree of symmetry.*

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*See 84 for the signification of π.

I. CLINIC CRYSTALS; *the interaxial angles not all right angles.*

1. *Triclinic crystals;* no interaxial angle a right angle. (hkl) a pair of *two* faces.

2. *Monoclinic crystals;* two interaxial angles are right angles; (hkl) a dome of *four* faces.

II. ORTHOCLINIC CRYSTALS; *the interaxial angles are all right angles.* $\alpha=\beta=\gamma=90°$.

3. *No rotary symmetry;* $a \lessgtr b \gtrless c$. *Rhombic* forms (hkl) an octaid of *eight* faces.

4. *Rotary Symmetry of* 90° *around c;* $a = b \lessgtr .c$ The *quadratic form* [hkl] is a dioctaid of 16 faces.

5. *Rotary Symmetry of* 90° *around each axis, a, b and c;* a=b=c. The *quadro-tesseral* form is a *triakisdioctaid* or *hexakisoctahedron* of 3×16 or 6×8, that is forty-eight faces.

6. *Rotary Symmetry of* 120° *around c;* $a=b\sqrt{3} \lessgtr c$. The *hexagonal* form is *tri-octaid* or a double twelve-sided pyramid of 3×8 = 2×12= *twenty-four* faces.

7. Rotary Symmetry of 120° around one axis, combined with rotary symmetry of 90° around another axis. The *rhombo-tesseral form*, geometrically the same as 5, but different in position and in structure.

54. All crystals of one kind of form and possessing the same degree of symmetry constitute a *crystal system* of the same name as the form. Thus all triclinic forms constitute the triclinic system, etc.

55. When the forms of different crystals are compared the elements of these crystals must be considered as *variables* (see 41, 8). The forms of higher symmetry thus arise through *special values* of these variables, so that the *systems pass gradually into one another.* Instead of forming distinct *classes* of crystals, the forms of higher symmetry are only limits or transition-values between those of other degrees of symmetry.

Thus the *quadratic forms* constitute a transition or limit between the rhombic crystals wherein $a=b$— and those wherein $a=b+^{\varepsilon}$, if $^{\varepsilon}$ is a variable positive quantity.

56. The elements of all orthoclinic crystals may be exactly represented by a *point* in a co-ordinate-plane, if a, the axis of X (horizontal) and c, the axis of Z (vertical), provided $y=1$ be understood. Then the ordinate at $x=1$ is the place of all quadratic forms, and on this line $c=1$ is the place of all quadro-tesseral, while above this point we have *acute* quadratic forms, below it we have *obtuse* quadratic forms. So also the ordinate as $x=\sqrt{3}$ represents all hexagonal forms, while in this ordinate the point $c=\sqrt{2}$ represents all rhombo-tesseral forms. The balance of the plane represents the rhombic crystals proper.

See my *Atomechanik*, 1867, p. 28—29.

57. The otherwise intricate study of the different holohedral and hemihedral forms in the crystals of higher degree of symmetry (48, 49, 50 and 51) becomes quite simple by means of the following analysis of the forms in rhombic crystals. For the sake of brevity we shall denote the eight faces of the holohedral rhombic pyramid by the letters p q r s (upper faces) and p′ q′ r′ s′ (lower parallel faces) as explained in 46.

To distinguish the holosymmetric holohedral form from the others which are either not holosymmetric or not holohedral (see 42, 43) we shall denote the full octaid by ω (h k l.)

58. The true hemihedral rhombic form is the *sphenoid;* the *right* σ [hkl] formed by the four faces p q′ r s′, and the left σ [$\bar{h}$kl] formed by p′ q r′ s.

59. We also distinguish the following *monozonal forms:*

Clinozonal, π (h k l) of 4 faces p q p′ q′.

Orthozonal, δ (hkl) of 4 faces p r p′ r′.

Also the *monopyramidal forms :*

Orthomonopyramid, ς (h k l) of 4 faces p q r s.

Deuteromonopyramid ς (h k l) “ “ “ p q r′ s′.

Protomonopyramid ξ (h k l) “ “ “ p′ q′ r s.

Of each of these forms there are two differing in the sign of one index.

60. By two of these letters before the indices of a form we denote those faces, which both separately contain in common. The most important cases are:

δ ς (h k l) composed of p and r′.
δ σ (h k l) “ “ p “ r.
ξ σ (h k l) “ “ p “ q′.
ζ π (h k l) “ “ p “ q.

Of each of these forms there are *four* differing in position.

61. *Twin-Crystals* are aggregates of two (or more) crystals united after some simple mathematical law, but having not all their axes and faces parallel. Taking any one of these individual crystals as firm, the position of the other individual is obtained by a rotation of 180° around some definite real crystal-line (axis, edge or normal to a face) in the first individual.

62. Before we can proceed to the special description of the crystal forms observed, we must explain the *principal systems of notation* in use, which differ more or less from our own.

63. *Miller's* notation (p q r) is the inverse of our own; for it gives the parameters as

$$\frac{a}{p} \quad \frac{b}{q} \quad \text{and} \quad \frac{c}{r}$$

Hence the face p q r Miller is identic with h k l Hinrichs, if

$$h : k : l = \frac{1}{p} : \frac{1}{q} : \frac{1}{r}$$

for all except the hexagonal forms. Miller's axes for the latter are triclinic $\alpha \beta \gamma \gtrless 90°$, and admit therefore of no very simple transformation to our own. By means of *Schrauf's* orthohexagonal symbols the transition from Miller's to our own symbols can, however, be readily effected.

64. The notation of *Weiss* is ha : kb : lc, without any restriction as to the order of these parameters.*

Our own notation results from this by adopting the *fixed* order of the succession of the parameters, (see 11) and thus becoming enabled to drop the letters a, b, c.

65. The notation of *Naumann* is far too symbolical and intricate to be of easy application. While a decided improvement of that of *Mohs*, it cannot be compared to those notations which give a concise and analytical expression of the crystal-face. (Weiss, Hinrichs,) or crystal-normal (Miller).

66. *Levy's* notation is used by only very few French crystallographers. It is a hybrid between the notation of *Hauy*—which was very excellent in the earliest stages of crystallography—and the notation of *Weiss*. This system of notation would long ago have been abandoned if the boundless national vanity of the French did not stamp the recognition of foreign merit an act of treason.

67. To substantiate our statements we give the different notations for a simple adamantoid, see 50:

Miller	[623.]
Hinrichs	[123.]
Weiss	a : 3a : 2a.
Naumann	2O3.
Levy	$b^{\frac{1}{3}}$ $b^{\frac{1}{2}}$ $b^{\frac{1}{3}}$.

68. We are now prepared to understand the systematic description of the observed crystal forms. We shall for each system always first give a synopsis of the forms

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*See the crystallagraphic works of *Rammelsberg* and the excellent monographies of *G. vom Rath*.

in general, that is the holohedral form (see 44 to 54) together with the specializations thereof resulting by specialization of the indices, including the hemihedral forms. In tesseral and hexagonal forms the latter will require special investigation.

69. Each system is next to be represented by some one of the excellent monographs of *Nicholas von Kokscharow*, given in his *Materialien zur Mineralogie Russlands*, published at Petersburg in five volumes of 400 pages 8vo. each, and accompanied by a most excellent Atlas of more than 70 plates in quarto. For the sake of brevity we shall refer to this work by adding the number of the volume and the page of the latter to the name of the author. Thus, v. Kokscharow III. 139, refers to vol. 3, page 139. Also, *Pl.* 69 is to stand for plate 69 in the Atlas.

We select this work of *von Kokscharow* because in a comparatively small bulk and at a moderate cost it gives so great a number of monographies.

If, however, the SITZUNGSBERICHTE der mathematisch-naturwissenschaftlichen Classe der Kaiserlichen *Akademie der Wissenschaften*, WIEN, are accessible, the best monographies ever published on crystal species will be at hand. We mention here only the following, which have appeared since 1860:

Von Zepharowich : Idokras, 1864, 49, I., 6–134, 13 plates.
" Anglesit, 1864, 50, I., 369–374, 1 plate.
" Epidot, 1862, 45, I., 381, 1 large plate.
" Unterschw. Kalk, 1862, 45, I., 499-510, 3 plates.
Zirkel : Bournonit, 1862, 45, I., 431–466, 7 plates.
Dauber : Rothbleierz, 1860, 42, 19–54, 12 plates, especially 3 large projections.
Krenner, Antimonit, 1865, 51, I., 436–481, 9 plates.
Auerbach, Coelestin, 1869, 59, I., 436–481, 9 plates.
Brezina, Schwefel, 1869, 60, I., 1 plate.

Poggendorff's Annalen bring, at times, good crystallographic monographies, especially from *G. vom Rath.*

70. Finally we shall give a somewhat general description of some characteristic *isomorphous group*, (see Physics 183 and 194—196) *of artificial crystals for each system.*

That the study of the monographies should go hand in hand with the study of the actual crystals, both native and artificial, is simply a matter of course. It is also expected that the student constructs our *Quenstedt* Projection from the given data for each of the native crystals.

CHAPTER IV.

Crystal Descriptions*.

A. Crystals without rotary Symmetry.

I. TRICLINIC CRYSTALS.

Elements : $\alpha \lessgtr \beta \lessgtr \gamma \; 90^\circ$. a $\gtrless$ b $\lessgtr$ c.

71. The holohedral form contains (see 44) only two faces which are parallel; it is a *tetartopyramid.* According to the position of these faces we have the following simple forms in this system (see 14):

1. PYRAMIDAL FACES: the *upper-right* (hkl); also the *lower-right*, the *upper-left* and *lower-left Tetartopyramid.*
2. PRISMATIC FACES: the *right* (hk∞) and the *left Hemiprism.* The *upper* (∞kl) and the lower *Protohemidoma.* The *upper* (h ∞l) and the *lower Deuterohemidoma.*
3. PINACOIDS: The *Basopinacoid* (∞∞1) the *Protopinacoid* (∞1∞) and the *Deuteropinacoid* (1∞ ∞).

Hemihedral forms are impossible in triclinic crystals.

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*We give merely a list of the examples used by ourselves in our lectures, together with a reference to the original observations which we give reduced to our notation. We also make use of the plates here referred to and carefully exhibit to our students the best demonstrative specimens accessible, both of native and artificial crystals. A *practicum* follows the lectures.

72. ANORTHITE. See *Von Kokscharow*, IV., 290—257, Pl. 70, 71.

Vom Rath, Pogg. Ann. 138, p. 449, p. 464.

Tschermak, Sitzungsberichte, Wien, 1864, Bd. 50, I., p. 566—613; a most important paper.

Total 35 forms with 70 distinct faces.

A very critical monogrophy is that of *G. vom Rath* on AXINITE, Pogg. Ann. 1866, Bd. 128, pp. 20—46 and 227—259.

73. BLUE VITRIOL. See *Kupffer* in Rammelsberg, Neueste Forschungen in der Krystallograph. Chemie, p. 50. Also *Pape* in Pogg. Ann. 1868, 133, p. 364. Observed 15 forms, embracing 30 faces.

Wohlwill's isomorphous selenates of copper, iron and zinc, with the same number (5) of atoms of water.

II. MONOCLINIC CRYSTALS.

Elements: $\alpha \gtrless \beta = \gamma = 90°$. $a \lessgtr b \lessgtr c$.

74. The simple holohedral monoclinic form is composed of four faces at most (see 45). According to the special values of the indices we have (see 14) the following forms:

PYRAMIDAL: The *upper* (hkl) and the *lower* Hemipyramid; each of 4 faces.

PRISMATIC: The vertical *prism* ($hk\infty$) and the *deuterodoma* ($h\infty l$) each composed of four faces. The latter is more commonly called the *clinodoma*. The *upper* (∞kl) and the *lower protohemidoma* is each composed of two faces only; they are often termed orthodomas.

PINACOIDS: The bassopinacoid ($\infty\infty 1$) forms the *oblique base*; the protopinacoid ($\infty 1 \infty$) constitutes the *orthopinacoid*; and the deuteropinacoid ($1 \infty \infty$) is useally called the *clinopinacoid*. These names have reference to X or a as horizontal (ortho-), Y or b as inclined (clino-) axes, while Z or c is vertical.

No hemihedral forms occur, but hemimorphism is possible.

75. PYROXENE. See *Von Kokscharow*, IV., 258—385 Pl. 65—69. 48 Forms with 176 faces.

76. HEXHYDRAHED HAUEROIDS:* Observations of *Brooke*, *Marignac*, *Miller*, and *Rammelsberg* in the latter's Krystall. Chemie. Also *Von Hauer's* Krystallogenetische Beobachtungen, Sitzungsberichte, 1860.

Eleven forms with 38 faces.

III. RHOMBIC CRYSTALS.

Elements: $\alpha = \beta = \gamma = 90°$. $a \gtrless b \gtrless c$.

77. The simple holohedral rhombic form is the octaid (hkl) of eight equal faces (see 46). We distinguish (see 14) the following forms:

Pyramidal: The octaid (hkl). Eight faces.

Prismatic: The vertical rhombic prism (hk∞). The protodoma (∞kl) called the *macrodome* and the deuterodoma (h∞l) called the *brachydome* if a > b. Each of these forms contains four faces.

Pinacoids: The basopinacoid (∞∞l), the *macropinacoid* (∞l∞) and the *brachypinacoid* (l∞∞), each of two faces.

The only closed hemihedral forms are the *positive* σ (hkl) and *negative sphenoids.* Compare 58. These sphenoids occur on the hepthydrated zinc and magnesium sulphates. See Physics, 184, 185.

Hemimorphism on a zinc silicate. Compare 59.

78. TOPAZ. *Von Kokscharow*, II., 198; II., 344; III., 195; III., 378; V., 34. The seven plates 38, a, b, c, d, e, f. Thirty-two forms embracing 184 faces.

79. POTASSIUM SULPHATE. See *Mitscherlich* in Rammelsberg, Kryst. Chemie. Nine forms embracing 38 faces.

This form is the representative of 15 sulphates and selenates, 3 chromates and manganates, 4 permanganates, 4

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*See *Hinrichs*, Sitzungsberichte, Wien, 1870, Bd. 75, Abthl. I.

perchlorates, 9 silicates, 4 formiates; in all 39 salts which I have termed *Barytoids*,* already carefully determined in my *Note sur la forme cristalline des sulfates*, Comptes Rendus, 1869, t. 68, p. 344. See also my contributions to Molecular Science, 1869, No. 3, p. 41—43.

For more complete description of this *Barytoid Form* see the monographies on Celestite, Anglesite, etc., quoted in 69. Compare also 90, the silicate *Phenacite*.

B.—Crystals with Rotary Symmetry.

IV. QUADRATIC CRYSTALS.

Elements : $\alpha = \beta = \gamma = 90^\circ$. $a = b \lesseqgtr c$.

80. The holohedral and holosymmetric simple form in this system results from two octaids (hkl) one of which having been turned a right angle around the vertical axis Z, see. 48. To make this composition more apparent it is best to draw the traces of the faces on the plane X Y. I mark the trace of an upper face by a full line, of a lower face by a dotted line, and of upper and lower face by a line crossed. Also, to distinguish the two octaids, I draw the traces of the octaid (hkl) 0° in black, those of (hkl) 90° in red. This expediency is really necessary for the study of the many, often intricate forms of quadratic crystals; besides such traces are in many respects more useful than the axonometric drawing of the crystal form.

The great number of distinct quadratic forms compels us here to give but the most important ones; in a separate memoir a thorough treatise of these forms will soon be given.

81. The holohedral holosymmetrical *dioctaid* (48) or *Dipyramid* of 16 faces is (Fig. 174)†

$$\omega\,[hkl] = \omega\,(hkl)\,(0^\circ + 90^\circ).$$

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*Sitzungsberichte, Wien, 1870, Bd. 62, I. Abth., page 9 of the memoir; also p. 13,

†We add in brackets, the *figure* in *Von Lang*, *Krystallographie*, and adopt the nomenclature given in that most excellent work. This will make the identification of forms easy without special figures here added.

The *diprism* (Fig. 175) ω [hk∞] of eight faces, and the *pinacoid* ω [∞ ∞ l] of two faces constitute the limits of this form in regard to l.

The *protopyramid* ω [hhl] (Fig. 176) and the *deuteropyramid* ω [h∞ l] (Fig. 177) (Fig.178) and the *deutroprism* ω [l∞ ∞] (Fig. 179.)

These 7 forms are holoquadratic holohedral, and therefore marked ω.

Of hemihedral holoquadratic forms we mention :
the *trapezohedron*, σ [hkl]. (Fig. 180).
the *deuterodisphenoid*, ζ [hkl]. (Fig. 183).

Hemiquadratic forms are also very numerous; here may be mentioned :
the *tritopyramid*, δ [hkl]. (Fig. 185).
the *tritosphenoid*, $\zeta\ \delta$ [hkl]. (Figure 191.)
Compare 57 to 60 inclusive.

82. IDOCRASE or VESUVIAN. *Von Kokscharow*, I., Pl. 10, 11. A masterly monography is that of *Von Zepharowich* on the crystal forms of this mineral, See Sitzungsberichte, Wien, 1864, 49, I., pp. 6—134, with 13 plates. Observed 46 forms of 488 faces.

Another example of quadratic crystals :

ZIRCON, *Von Kokscharow*, III., 139, 193; IV., 35; V. 103; Pl. 48, 49, 50, 51.

83. *Ammoniated Silver Sulphate.* See *Mitscherlich* in Rammelsberg Kryst. Chemie. Four forms of 18 faces. Isomorphous therewith the corresponding selenate and chromate; also the ammoniated platinum sulphate.

Nickel sulphate, crystallized at about 20°, forms readily large and most beautiful quadratic crystals. See Rammelsberg, Kryst. Chem.

V.—Hexagonal Crystals.

*Elements** : $\alpha = \beta = \gamma = 90°$. $a = b\sqrt{3} \gtrless c$.

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*For the same absolute length of the vertical axis c (*Hauptaxe*) we may have our deutroaxis b either equal to the *Nebenaxe* a or to the *Zwischenaxe* s of *Quenstedt* and *Hochstetter*. Accordingly our proto-axis a will be either b = 2 s or 3-2 a of these authors. For the sake of brevity we shall term the first the system of A, the second the system of S. The latter is the most common, and gives the fundamental [∞11].

84. The octaid (46) in its primary position 0° and after rotation of 120° and 240° gives as resulting form, the holohexagonal holohedral holosymmetrical form:

$$\omega\,[hkl] = \omega\,(hkl)\ (0^\circ+120^\circ+240^\circ)$$

as the fundamental simple form of these crystals. It is the *dipyramid* (Fig. 131, *von Lang*, see note to 81) of 24 faces. See 49. All other hexagonal forms result, of course, from this form. Their generation and structure must be studied by the traces, as directed in 80; the third trace for 240°, may conveniently be drawn in blue, if the second (120°) is in red, and the first (0°) in black. Compare 57 to 60.

The number of forms in hexagonal crystals is still greater than in quadratic forms. Hence only a few will be given here. For a more exhaustive deduction of the hexagonal forms see notice at close of 80.

85. HEXAGONAL FORMS proper, or holohexagonal forms are:

HOLOHEDRAL
Dipyramid, ω [hkl]. Fig.* 131.
Diprism, ω [hk∞]. Fig. 132.
Protopyramid, ω [∞kl]. Fig. 133.
Deuteropyramid, ω [hhl.] Fig. 135.
Protoprism, ω [∞ l∞].
Deuteroprism, ω [ll∞].
Pinacoid, ω [∞ ∞ l].

HEMIHEDRAL
Ditrapezohedron, σ [hkl]. Fig. 137.
Protosphenoid Pyramid, γ [hkl]. Fig. 138.
Deuterosphenoid Pyramid, ξ[hkl]. Fg. 142.

86. RHOMBOHEDRAL FORMS, or protohemihexagonal forms are:

HOLOHEDRAL
Scalenohedron. π [hkl]. Fig. 146.
Rhombohedron, π [∞ kl]. Fig. 148.

HEMIHEDRAL—*Trapezohedron* ξ π [hkl]. Fig. 152.

87. GYROIDAL FORMS, or deuterohemihexagonal forms are:

HOLOHEDRAL: *Tritopyramid*, δ (hkl). Fig. 156.

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*See Von Lang's Krystallographie.

HEMIHEDRAL: *Tritohemipyramid* $\eta\,\delta$ [hkl]. Fig. 162.

88. Lateral hemimorphism (ξ or η, see 59) is not more common in hexagonal forms than terminal hemimorphism; (ζ in Turmaline;) hitherto, however, the former, have been overlooked.

89. BERYL, *Holohexagonal*, *Von Kokscharow*, II., 356; III., 72; IV., 125, 258. Pl. 12, 13, 14, 15, 16. Observed 18 forms of 266 faces.

90. PHENACITE; *Rhombohedral.* *Von Kokscharow*, II., 308; III., 81; V., 329; Pl. 39, 40, 41, 42. Observed 12 forms of 80 faces in all.

Another excellent rhombohedral example is:

CALCITE. *Hochstetter*, Denkschriften, Wien, 1852, Bd. VI., pp. 89—124, with a splendid large projection.

91. MARIGNACOIDS, the Chloroid–Salts $\pi\, a_3\, \nu$ wherein a any chloroid Fl, Cl, Br, Io, to which are *added* n atoms of water (n = 1, 2, 3 observed) and

π = Mg, Zn, Cd; Mn, Fe, Ni, Co; Cu; Nd.
ν = Pt, Sn, Si, Zr.

See also the observations of *Topsoe*, Oversigt Kgl. D. Vid. Selsk. Forh. 1868, p. 123—157, and 1869, p. 73—97.

VI. A.—Quadro-Tesseral Crystals.

Elements: $\alpha = \beta = \gamma = 90^\circ$. a = b = c.

92. The *Adamantoid* or *Hexakisoctahedron* ω [hkl] results as shown in 50 by taking successively each of the three equal axes as quadratic axis for a rotation of 90° of the holo-rhombic octaid ω (hkl).

If, however, we *omit* this rotation, but only turn the vertical l of the octaid successively into the three axes, we obtain the hemihedral form of twenty-four faces,

$$\frac{\omega}{2}\,[hkl] = \omega\,(hkl)\,0^\circ + \omega\,(hlk)\,0^\circ + \omega\,(lhk)\,0^\circ.$$

called the *Diploid* by *Von Haidinger*; also known as the *Diakisdodecahedron.*

This form is the true hemihedral form of tesseral crystals. No other crystals admit of this kind of hemihedry. Hence this form is properly denoted by $\frac{\omega}{2}$.

93. If instead of the octaid ω (hkl) (see 57) we rotate the sphenoid σ (hkl) (see (58) we obtain the

σ [hkl] *Sphenadamantoid.—Haidinger.*
(Hexakistetrahedron.)—*Borazitoid.*
$\frac{\sigma}{2}$ [hkl] *Sphenodiploid.—Tetartoid.*
(Diakishexahedron.)

94. If we rotate the orthozone δ (see 59) we obtain δ [hkl], the *Gyroid* of *Von Haidinger*, having 4. 2. 3 = 24 faces, which are equal, irregular pentagons. The $\frac{\delta}{2}$ [hkl] is a Tetartoid. But these gyroquadrotesseral forms have, as yet, not been actually observed.

The same is true for the forms π and the monopyramidal forms ξ ε α, see 59.

95. By the variation of the indices each of these four-general ω, $\frac{\omega}{2}$ σ $\frac{\sigma}{2}$ gives rise to a great multitude of specific forms. Of the latter those which contain exclusively the *limits* of the indices (1 or ∞) are especially important.

For h = k = l = 1 the holohedral forms *geometrically* coincide in the regular *octahedron* ω [111] = σ [111] and the hemihedral in the regular *tetrahedran* $\frac{\omega}{2}$ [111] = $\frac{\sigma}{2}$[111]. But *crystallographically* the hemihedral forms have but *one half* as many faces; for in ω [111] each face is the result of *six* coincident planes, but in $\frac{\omega}{2}$ [111] only *three* faces coincide. This difference largely influences the resultant combinations.

For h = k = 1 and l = ∞ the regular *Dodecahedron* results, while h = 1, k = l = ∞ gives the regular *Hexahedron*.

It will readily be seen, that [111] is generated by the pyramidal faces 111 in the rhombic octaid, while the dodecahedron results from the domes 11∞ and the hexahedron from the pinacoids, 1∞ ∞.

96. These forms should be placed in the following order, so as to constitute a complete *system* :

111.... ...Octahedron........111

ω $\frac{\omega}{2}$

Dodecahedron........Hexahedron......Dodecahedron.

11∞ σ ∞1∞ $\frac{\sigma}{2}$ 11∞

111.......Tetrahedron.......111

All other forms take their place in this system between the respective limits according to the actual values of their indices. The whole system of forms thus is composed of four equilateral triangles, three of which have already been given in the classical *Handbuch der bestimmenden Mineralogie* of *Haidinger*, (pp. 88—89; p. 102 and p. 107.)

97. The following are the principal intermediate quadrotesseral forms with their composite names and the specific names proposed by *Von Haidinger.* In our formula we have always $h<k$. The first number indicates the Figure in *Von Lang's* Krystallographie:

100....Triakisoctahedron.... ω [hhk]......... *Galenoid.*
99....Trapezohedron....... ω [hkk]......... *Leucitoid.*
101....Tetrakishexahedron .. ω [hk∞]........ *Fluoroid.*
106....Trigondodecahedron.. $\frac{\omega}{2}$ [hkk] .... *Kyproid.*
107....Triakistetrahedron .. $\frac{\omega}{2}$ [hhk]....... *Deltohedron.*
112....Pentagonaldadecahedron σ [hk∞].. *Pyritohedron.*

Of each of these intermediate forms several have been observed. The same is true for the forms [hkl] see 92 and 93. The most common are those wherein h, k and l are 1, 2, 3, 4, 5 and 6.

On most of these forms we can readily distinguish the octahedral edge o, the dodecahedral d and the hexahedral h. For these edges the *internormal* angles have been calculated and may be given in a table.

Quadrotesseral Forms observed.

98. Magnetite.—*Von Kokscharow*, III., 47, Plates 45, 46.

This species is undoubtedly *quadrotesseral.* Observed forms all holohedral, viz:

c	1∞∞	t	133
d	11∞	z	2–5–15 or 3–5–3.5
o	111	x	5–15–21 or 5–3.5–3.7

Total 146 faces.

All the members of the great *spinel-group* crystallize in qnodro-tesseral forms. Also galenite, halite, etc.

To this type belong also many artificial crystals, especially many chloroid-salts.

The grand group of *alums* (Physics, 194) form beautiful quadro-tesseral crystals, the formula of which is given by me in Sitzungsberichte, Wien, 1870, I Bd., p.

VI. B.—Rhombotesseral Forms.

Elements: $\alpha = \beta = \gamma = 90$. $a = b\sqrt{3}$.

S: $c = b\sqrt{2}$, if b = Quenstedt* s; cube ∞ll;

or A: $c = b\sqrt{2}$, if b = Quenstedt a; cube lll.

99. For the general features of these forms, see 51.

The forms of the tesseral system may be expressed as rhombotesseral by reducing to our own the symbols given by *Hochstetter*, Denkschriften, Wien, VI., p. 116—121.

100. Mathematically the rhombotesseral forms (99) do not differ from the quadrotesseral forms described before. But physically and chemically, and therefore crystallographically, the rhombotesseral forms are wholly distinct from the quadrotesseral forms.

Thus Fluorite and Halite are both tesseral. But

$$\text{Fluorite is...}\, Ca \left\{\begin{matrix} Fl \\ Fl \end{matrix}\right.$$

while Halite is Na Cl; or chemically the atoms of the former are composed of three atoms, the latter of two only. Physically the latter has a cubical cleavage—yielding rectangular blocks, while the latter has the rhombohedral and basical cleavage resulting in octahedral fragments.

Pyrite $Fe\ S_2$ is also rhombotesseral; its hemihedral form is in this position *trapezoidal*, precisely as we have it for the rhombohedral quartz, $Si\ O_2$.

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*Compare foot-note to 84.

From among artificial crystals the nitrates of lead, barium and strontium are rhombo-tesseral; their formula is $R\ X_2$ where $X = O_3\ N$, hence their chemical constitution the same as that of pyrite; they also exhibit the trapezoidal faces.

GARNET must also be considered a rhombo-tesseral species; its formula is $R_2\ X_3$ wherein $X = R\ O_4\,Si$. For its form, see *Von Kokscharow*, III., 1, 79, 230, and Plate 44.

The numerous so-called double chlorides, which are really *chloro-salts*, crystallize tesseral if they contain six atoms of the chloroid, and are undoubtedly rhombo-tesseral.

In many cases it is, however, at present impossible to distinguish between the rhombo-tesseral and quadro-tesseral forms.

◆

CHAPTER V.

Crystal Symmetry.

101. In *abstract geometry* one polyhedron is as possible, as another. Hence the elements a, b, c, α, β, γ of such polyhedron can have *any* value, and the indices h, k, l may also be any numbers, rational or irrational.

The act of crystallization of any substance represents therefore, geometrically a double selection. First, *specific*, the elements assuming only definite values from among all possible values; and, secondly, from among all geometrically possible faces only those are selected which make the indices *rational*, *entire*, and *simple* numbers, giving the different *varieties* of the same specific form.

102. From this double geometrical selection it follows: I. that the *elements of a crystal* represent the inclination (α, β, γ) of the three systems of parallel lines along which the atoms of the substance are distributed and the *mutual* *distances* a, b, c of these particles along these lines;[*] and, II., that the indices h, k, l represent the *rates of growth* along these three directions. The first characterizes the *species*, the second the *variety* of the crystal forms.

103. If so important results concerning the molecular structure of solids depend upon the crystallographic elements and indices, the reality of these elements and indices should be most critically established.

We shall in the subsequent only give the outline of such a research.

104. The number of varieties of forms actually observed for many substances is quite large. The number of faces observed on Pyroxene is 176, Topaz 184, Beryl 266, and Idocrase 488. Now all these faces are for any one substance *accurately* expressed by the one set of elements and the simple indices given in last chapter (see 75, 78, 89 and 82.)

105. The substance richest in varieties of crystal forms is the rhombohedral *calcite.* In *Hauy's* atlas (1801) these forms occupy already four plates in quarto. *Bournon* Traite complete de la chaux carbonate fills 3 volumes (1808.) *Levy* gave 178 figures of calcite crystals (1837.) *Zippe's* Übersicht der Krystallgestalten des rhomboedrischen Kalk-Haloids[*] of 1851, enumerates 700 varieties of habitus, and of simple forms, 42 rhombohedra, 85 scalenohedra, 7 dihexahedra and several prisms, or about *fifteen hundred distinct faces!* These were united in one large projection by *Hochstetter*, 1854. Since then *Hessenberg* has discovered many new forms, yet *G. vom Rath*[‡] considers the description of the forms of calcite far from complete, although he himself at the same time richly adds to these forms!

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[*] The atomic structure of quadrotesseral and rhombotesseral crystals is therefore radically different. Compare 100.

[†] Wiener Denkschriften, Bd. III.

[‡] Pogg. Ann. 1867, Bd. 132, p. 387—404 and 517—550, with 1 plate. Also Pogg. Ann. 1868, Bd. 135, p. 572—579. He adds, so far as I can enumerate, 5 new rhombohedra, 5 scalenohedra, and 2 dihexahedra, or more than *one hundred new faces!*

Now it is a *fact*, that all these faces are expressed accurately by the *same* elements and by simple rational indices!

106. The indices are, in the immense majority of cases, not only rational whole numbers, but also *very small whole numbers.* Compare the descriptions given, Chapter III. However, in a few rare cases the indices become rather high; but then the corresponding faces only occur as narrow *transition belts* between faces of very simple indices. These high indices result furthermore from the simple indices hkl of the dominant form by multiplication with a usually large factor *f* and the addition of some small numbers to one or two of the resulting products; so that the *vicinal face*[†] resulting has indices like

$$f.\mathrm{h}+\mathrm{p} : f.\mathrm{k} : f.\mathrm{l}+\mathrm{p}.$$

107. *Von Kokscharow* observed the vicinal face 61, 20, 61, or 3.20+1 : 1.20 : 3.20+1, near s = 313 on Vesuvian. See also *Von Zepharowich*, Idocrase, p. 127—128, who unites the four faces n, w, m, k of *von Kokscharow* in one pyramid. Compare 82. Also, *Kenngott* Übersicht 1862—1865, p. 182—183.

On Fluorite von Kokscharow (V. 200) observed the adamantoid $_{\omega}$[15-33-55] where the indices are composed of the prime factors 3, 5 and 11. This is most frequently the case where any one index, for example c, is much greater than the others; thus in 236 we have l = h. k.

108. The elements are, for any given substance, really constant. But they vary with the temperature, as is shown in any work on crystallophysics. Compare Contrib. III., p. 43—45.

If the substance is not chemically pure, the elements of its form will of course be influenced by these accessory ingredients. For examples see *Auerbach* on celestine (quoted in 69) and *von Kokscharow* on apatite (V. 86–100) Compare 55; also 91, 79, 76.

[†] *Websky's* term, which we adopt, without, however, adopting the peculiar views of *Websky*.

109. The correctness of these elements implies certain mathematical conditions for the forms of higher symmetry, see 46 to 51.) Thus quadratic forms must be *exactly* quadratic; hexagonal forms must be *exactly* hexagonal. On this point we have very accurate measurements, especially by *von Kokscharow* on Beryl (89) and by *von Zepharowich* on Idocrase (82). Most crystals, it is true, do not possess the perfect, mathematical regularity of form required by the above conditions.

110. *Von Zepharowich* found, however, *one crystal* among 54 crystals of Idocrase from the Mussa-Alpe in Piedmont, which had its four pyramidal faces p = 111 inclined under the same angle of 142° 45′ 0″ (internormal, 37° 15′ 0″) to the base c = ∞ ∞ 1. See l. c. p. 65, I.

But the deviations observed on the other crystals prove by their very minuteness, and by their variations, that they are due to accidental causes, such as slight impurities, position during growth, pressure, etc. Thus No. 11, Fig. 24, of *von Zepharowich* (l. c. pages 62–63), a grass-green crystal, 11 mm high, 5 and 6 mm across, gave for the internormal angle between any two adjacent faces p values ranging from 50 40′ to 50° 41′. But a variation of one minute on a crystal of this size is less than the variation of one-thousandth of a millimeter in the linear dimensions!

111. *Von Kokscharow* made similar careful measurements on two fine crystals of Beryl. He found the angle of the prism truly 120° 0′ 0″, by repeated measurements (compare 89), and the interfacial angle between the six pyramidal faces t and the base P varied only about 20 seconds from 160° 3′ 42″, the mean value for his crystal No. 2. Since that crystal had a diameter of about 5 mm only, and as the linear extend of the facets t was less than one-fifth the diameter, this deviation amounts to less *than* *one ten-thousandth part of one millimeter*, for the linear position of t on the lateral edges of the crystal.

112. Even the crystals of *diamond*, which as a rule have curved faces, exhibit at times almost mathematically perfect crystals. The colorless diamond described by *von Kokscharow* (V. 397) was such an octahedron; in one zone the deviations from the normal interfacial angles 109° 28 16″, and 70° 31′ 44″ were only — 14, — 44, — 46, — 16 seconds.

113. Crystals do therefore really exhibit that two-fold geometrical selection (101) whereby they are distinguished as true individuals from all other mere polyhedra.

Artificial crystals are often of most surprizing regularity, not only in angles but also in their linear dimensions. By changing the conditions of crystallization we can produce quite regular or more distorted crystals. See the careful observations and the description of most beautiful crystallizations by *Karl von Hauer*, Wien, Sitzungsberichte, 1860, Bd. 39, pp. 438–447, and pp. 611–622; also Bd. 40, pp. 539–554, with 2 plates, and pp. 589–606 with one plate.

114. The degrees of symmetry described are merely *limits* of form, whereto many neighboring forms approach, or *transition forms*, having allied forms on either side. Compare 55 and 56.

This is not only true in regard to the axial dimensions, but also in regard to the *correlate faces* embraced in one simple form in the higher forms of symmetry.

115. Thus in *triclinic forms* we have very frequently simple forms which correspond to a monoclinic simple form, and would therefore form such, if only the elements were correspondingly changed. Compare in Anorthite (72) a and m; p and o; these four together would even form the orthoclinic octaid. Also observe how near β and γ are to 90°.

Furthermore we have the monoclinic combinations b and β; w, v; g, u; etc., etc. Also T, l; z, f. Compare *Haidinger*, Handbuch, p. 223, Fig. 336, and his remarks thereon. Also, *Tschermak's* genial work on the *Feldspars*, Wien, Sitzungsberichte, 1864, Bd. 50, I., p. 566–613.

117. *Rhombic crystals* possess often all faces demanded by quadratic symmetry, if the axis a is nearly equal to b. For example in *epsomite* and in white vitriol. Observe the horizontal projection of epsomite in *Rammelsberg's* Krystall. Chemie, 1855, p. 87. This near approach to higher symmetry is also manifested by the frequency of the sphenoid in this species.

118. Rhombic crystals, wherein a is nearly b $\sqrt{3}$, have all the forms characteristic of *hexagonal* symmetry. This is strikingly the case with all the members of the isomorphous group described in 79. The hexagonal prism is p and b; pyramid o and q^2, another $^{o}/_{2}$ anb q.

In phenacite (90), a *member of this group*, the axis a is *exactly* equal to b $\sqrt{3}$, and here these forms therefore not merely represent or simulate, but really *do constitute* a true hexagonal symmetry!

In Topaz $a - b\sqrt{3} = 0.160$, a rather large difference. Still we have the planes necessary for many hexagonal forms.

Compare also *Discrasite*, the prismatic angle of which is 119° 59′.

119. *Quadratic crystals* have most of the characteristic faces of quadro-tesseral crystals, if the vertical axis c is nearly equal to the horizontal axis. Thus in the quadratic *chalcopyrite* $c = 0.98556 = a - 0.01444$ where $a = b = 1.00000$; hence we find the habitus of chalcopyrite totally quadrotesseral, even in its hemihedral forms. This simulation is so great, that the form of chalcopyrite was considered really quadro-tesseral until *Haidinger* discovered its true quadratic form.

Idocrase (see 82) gives $2\ c = a + 0.07508$; hence it has also a quodro-tesseral symmetry, as shown by *Haidinger*, Handbuch, p. 214.

120. *Hexagonal crystals* have nearly a rhombotesseral symmetry, if their vertical axis c is nearly $b\sqrt{2} = 1.414$ b or $b' \sqrt{{}^3/_2} = 1.215\ b'$. Cases are quite frequent where the rhombohedron is either near 90° or near 120°.

121. But besides the above relations between the different degrees of symmetry we have many others. In fact, any degree of symmetry may and does approach any other very closely if the elements differ but little *numerically.* Hence the first observers assume often a higher degree of symmetry than more accurate observations can sustain (compare 119), while, inversely, distorted crystals may for some time hide a higher degree of symmetry.

The trihydrated potassium cyanoferrate* has by *Bunsen* and *Rammelsberg* been described as quadratic; but *Wyrouboff*† found it to be monoclinic, having the inclination $\alpha = 89° 27$ instead of 90°, while $a = 0.395$, $b = 1.000$, $c = 0.401$. The differences between the real and quadratic elements are only 33 minutes for the interaxial angle α and $0.006 = c - a$.

Tinfluoride, $Sn\ Fl_2$ is monoclinic (*Marignac*); but very nearly tesseral.

Cryolite is triclinic (*Websky*, 1867); but its three pinacoids differ only 24, 10 and 1 minute from being at right angles to one another, and the axes are also nearly equal. Hence it is very nearly tesseral.

Such cases become quite numerous, when the crystal elements are critically compared and not merely mechanically arranged in formidable tables.

122. From this it appears that the classification of substances according to their crystallographic symmetry (or system) iz a crystallographic absurdity; and every attempt of the kind has served to prove that such a classification leads to physical impossibilities and chemical monstrosities. Compare Atomechanik, § 352—254.

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*Yellow prussiate of potassa.

†Annales de Chimie et de Physique, 1869, T. 16, p. 293—301.

123. By overlooking these connections between the various crystal forms, the different degrees of symmetry were considered *qualitatively* radically different, while in fact they are only *quantitatively*, and often to but a very slight degree different from one another. Hence some crystallographers have been led to the monstrous invention called dimorphism. Compare *Atomechanik* pp. 31 to 41; also Contributions to molecular science, I. p. 9—15, and III.

124. To this same kind of physical monstrosities belongs the invention of *P. Groth*, termed by him *Morphotropic force* and morphotropy. This invention was presented to the Berlin Academy of Sciences by *G. Rose*, and has, therefore, been copied by several scientific journals. Compare 163.

125. Such monstrosities as the common view of dimorphism and this new morphotropy are rooted in the current perversion of *Mitscherlich's* discovery of isomorphism. He found that the salts of a certain chemical formula are of nearly the same form, and called this fact *isomorphism*; but his successors have succeeded to turn this fact upside down, and they now conclude that the vicariating atoms are of the same form.* Compare 159 and 156.

126. We sincerely regret to be compelled to this forcible protest against the continued disregard of the most elementary principles of mechanics by some of the leading crystallographers, especially of the Berlin school. Their monstrous speculations have, however, so deeply permeated the crystallographic literature that no protest can be too strong.

127. The introduction of *rotary symmetry* for the deduction of the quadratic, hexagonal and tesseral forms

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†*Rammelscerg* in Ber. Chem. Ges., 1870, p. 281, discovers (!) that hydrogen may be an isomorphous component in the phosphates $R'_3 O_4 P$, because one or two atoms R' may be hydrogen. The form of this phosphate is not determined by the atomic structure — but by hydrogen!

from the rhombic forms implies a twin-structure for these crystals of highest symmetry; but *a twin-structure composed of elements which in the several positions are of precisely the same dimensions.*

128. Such structure has been demonstrated by observation in several cases already; especially in *Quartz*, by *von Haidinger*, in the remarkable paper Über den Pleochroismus und die Krystallstructur des Amethystes, Sitzungsberichte, Wien, 1854, Bd. 12, p. 401. Also by optical observations of *Descloizeaux.*

These observations have been referred to the chemical formula and form of the quartz-atom by me in Atomechanik, §497—499, and in Über den Bau des Quarzes, Sitzungsberichte, Wien, 1870, Bd. 61, I. Abth.

129. But even if a crystal is not exactly hexagonal, but approximates to the axial ratio 1 : $\sqrt{3}$, such twin-structure becomes quite frequent. In *Haidinger's* memoir* "on the regular composition of crystallized bodies," I find the earliest thorough investigation of this structure.

The figure of cerusite, PbO_3C given by *Haidinger*, especially Figures 6, 7, 8 and 9, exhibit precisely the structure which for the axes a : b = $\sqrt{3}$: 1 would lead to true hexagonal forms. The same forms are frequent for the isomorphous anhydrous carbonates and other crystals of nearly hexagonal axes.

130. The beautiful crystals of *chrysoberyl*, and especially the *alexandrite* variety, exhibit this twin-structure often on a grand scale, forming most beautiful specimens. See *von Kokscharow*, Atlas, plates 63, 64. The axes are very nearly in the above ratio, because the angle of the vertical prism is 119° 46′, or only 14 minutes less than 120° 0′.

131. Twins demonstrating the quadrotesseral structure given by us have also been described by *von Haidinger* ;

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*Edinburgh Journal of Science, VI., 278. This paper I recently received from the author, whom I hereby most heartily thank for this and many kindred favors.

Fig. 423, p. 267 in Bestimmende Mineralogie. This crystal of chalcopyrite is a complex of six individuals, grown together so that indeed each extremity of the three rectangular axes forms the axis a of a quadratic crystal. This twin is so closely like a true tesseral, because the vertical axis of chalcopyrite is so nearly equal to the horizontal axes. See 119.

132. All forms are geometrically equally probable (101); and since the number of possible distinct forms is much the greatest for those lower degrees of symmetry due to unequal values of the elements, the less symmetric crystals should, geometrically be the most common.

133. If we suppose the axes determined to within 0.oo1 and the interaxial angles to within one minute, the relative *geometrical probability* of the different degrees of symmetry will be[*] for every t tesseral forms,

tesseral = t
hexagonal, h = 500. t
quadratic, q = 1000. t
rhombic, p = 1 000 000. t
monoclinic, m = 500 000 000. t
triclinic, cl = 250 000 000 000. t

134. But by a combination of these values with the actually observed number of each degree of symmetry. we obtained (l. c. page 15) the *true crystallographic probability* of

tesseral symmetry.........	800 000 000 000
hexagonal "	820 000 000
quadratic "	274 000 000
rhombic "	1 000 000
monoclinic "	2 000
triclinic "	1

135. It is therefore 800 000 000 000 to 1 that a new crystal has a tesseral rather than any *given* triclinic form, and 800 000 to 1 that it has the tesseral rather than any given rhombic form.

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[*] *Hinrichs*, Zur Statistik der Krystall-Symmetrise. Sitzungsb., Wien, 1870, Bd. 62, I. Abthl., p. 14.

136. The greater the number of conditions to be fulfilled to bring about a given form of symmetry, the more likely will that form be produced by the act of crystallization.

137. These remarkable facts apparently constitute a crystallographic paradox, thus indicating some general cause which mathematically accounts for these facts.

138. We have already in 1867 shown that the laws of chemical or atomic combination lead with mechanical necessity to an atomic structure of compounds which in the crystal-form is expressed by masses. See:

Programme der *Atomechanik*, oder *die Chemie eine Mechanik der Panatome*, von Gustav Hinrichs; Iowa City, Vereinigte Staaten, N. A., 1867.—44p., 4o.

139. Since then six memoirs have been published on special points of this programme; we shall, for the sake of brevity, refer to them as *Contributions to Molecular Science*, No. 1 to 6. Of these Nos. I. to IV. appeared in the *Proceedings of the American Association* for the Advancement of Science, Vols. 17 and 18 (1868 and 1869); they may, however, be obtained separately from *Brockhaus*, Leipzig. Nos. V. and VI. are contained in *Sitzungsberichte*, Wien, 1870, I. Abtheilung; namely

V. *Ueber den Bau des Quarzes*, in Vol. 61.

VI. *Zur Statistik der Krystall Symmetrie*, in Vol. 62.

Thus *Contrib. VI.* refers to this last mentioned paper.

140. In these "*Contributions*" and in "*Atomechanik*" the crystal form of a great many series of compounds has already been theoretically determined. We shall, in the next chapter, give a synopsis of this investigation, with references to the above works.

This synopsis is only to be considered a temporary substitute for a more extended work which has been a long time in preparation, but which official duties have not yet permitted me to bring to a satisfactory conclusion.

CHAPTER VI.

Crystal Atoms.

141. All chemical compounds which can be qualitatively and quantitatively expressed by the same *general formula*, constitute a *type.* Atomech. §232. Contributions, VI., p. 9—11.

142. In a *general formula* the symbols represent no given individual elements but either certain definite chemical compounds (Contr. VI., p. 9; No. 22) or *any one* individual element from a greater or smaller group of elements, (l. c. p. 7).

143. The elements are divided into *genera* (Atomech. 19 to 37, pp. 7—9, and Contr. IV., p. 48—51; also Contr. VI., p. 7), each of which is represented by a generic *Greek symbol.*

144. The elements are also distinguished as electropositive π and electronegative ν, together with intermediate α in ternaries. Contr. VI., p. 6.

145. The simple types therefore are only *specific functions* of π ν, and (if ternaries) α. If they are *hydrated* the atoms of water may often be combined with α and this combination denoted by ω. The same may be done with certain ammoniacal compounds. (Compare 83 above.)

146. Accordingly the general chemical formula

$$\psi\ (\alpha,\ {}^{\omega},\ \gamma)$$

does represent the great majority of the more important types as some definite function ψ of α, ω and ν.

147. The atom ψ has its constituent atoms in some geometrically well defined position in space. Let a, b, c represent the three axes of this compound atom, and α, β, γ the interaxial angles of the same.

148. Then those *atomic elements* are necessarily definite functions of ψ.

This can only be denied by those who dream of occult forces (124.)

149. *The interatomic distances* (between the compound atoms) are *proportional* to a, b, c; compare 102; also Atomech. Abschnitt IV. *Hence the atomic elements are the same as the crystal elements.*

150. Let, for b = 1, the interatomic distance along b be μ in some absolute measure. Then the crystal volume of the atom is easily calculated; and by comparison with the observed atomic volume the *mean atomic distance* μ is obtained.

151. For many orthoclinic crystals we have determined μ and obtained very remarkable results. This paper was presented August, 1869, at Salem, but not read for want of time. Proceedings, p. 275, No. 3.

152. The determination of the atomic elements as functions of 146 is so intricate an analytical problem, that it can only be solved by successive approximations. Atomech. §229—231.

153. As *first approximation*, we neglect the differences in weight between the constituent atoms; the resulting values of the elements we term the *normal elements of the type* 146. Atomech. 231; Contrib. 3, p. 36. The normal axes we call x, y, z.

154. The *actual values* (149) then result mechanically from the *perturbations* of the normal elements, exactly as the actual elements of any planet result from the perturbations of the other planets affecting its normal elements, determined by the sun alone.

155. Let these *perturbations* be ξ, η, ζ, then we have

$$a = x + \xi \qquad b = y + \eta \qquad c = z + \zeta$$

Compare Atomech. 233; Contrib. 4, p. 36. Similarly for the interaxial angles.

156. Hence it follows:

1. *The different members of the same chemical type have nearly the same crystal elements;*

2. *But these elements may belong to all degrees of symmetry according to the numerical values of the linear and angular perturbations, resulting from* 146.

157. For a general confimation hereof see Contrib. VI., pp. 9—11.

In this table the degree of symmetry of the observed n members of any type or genus is expressed by the formula

$$\text{n}\ldots\ldots\ldots\ldots\ldots\text{q. t. h.}\frac{\text{p}}{\text{m. tr}}\ldots\ldots\ldots\text{R.}\frac{\text{p}}{\text{cl}}$$

wherein *q* the number of quadratic members, *t* the tesseral, *h* the hexagonal, *p* the prismatic (or rhombic), *m* the monoclinic and *tr* the triclinic members. Also, R the sum of g't and h, or the total number of members having rotary symmetry, and *cl* = m and tr the clinogonal species.

158. Thus the *Barytoid Sulphates*, that is the normal sulphates (79) including three observed selenates, give the following numerical values:

$$15\ldots\ldots\ldots\ldots0.\ 0.\ 2.\frac{13}{0.\ 0}\ldots\ldots\ldots2.\frac{13}{0}$$

ranging over two different degrees of symmetry the rhombic and hexagonal; but the angle of the rhombic prism is nearly 120, so that these forms are quantitatively very close.

159. The above principle (156) represents true *isomorphism* or homoeomorphism; what is usually taught under isomorphism is false in fact and absurd in principle*. Compare 125.

160. In conclusion we shall enumerate the types which we have thus far more carefully determined by theory (15—155) and confirmed by existant observations.

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*The relation between the number of atoms of the negative elements and the degree of symmetry put forth in 1867 as original by *J. D. Dana*, the editor in chief of the American Journal of Science, resulted evidently from hasty and illogical study of my manuscript on the crystalline form of anhydrous carbonates, which manuscript with figures was in the hands of that editor several months prior to the publication of his "original discovery." See *Documents* relating to the history of Atomechanics, Iowa City, May 1868. Also, *Remarks* on a recent Editorial in the American Journal of Science, Iowa City, December, 1868.

161. The *Monaries* A or elements; see Atomech. §256—264.

162. The *Monides* $\pi\ \nu$; see Atomech. §265.

163. The *Deutides* $\pi\ \nu_2$; see Atomech. §§267—301. Also Contrib. I., p. 5, pp. 9—15. III., pp. 37—38, and p. 104. Contr. V. Contr. VI., p. 9. We sent December, 1868, a paper, giving a close discussion of 53 compounds of this type to *G. Rose.*

164. The *Tritates* $\pi\ \omega_3\ \nu$. Atomech. §§. 302—356. Contrib. III., pp. 38—41, also pp. 44—45, and VI., pp. 9—11.

165. The *Tetrates* $\pi\ \omega_4\ \nu$; see Atomech. §. 361—369 for spinnelloids; my "Note sur la forme cristalline des sulfates" mentioned in 79 for the barytoids. Also Contrib. III., p. 41—45, VI., p. 13.

166. Other more intricate types have already been partially determined. Atomech. §§. 370—379; also here 89, because 2 c as vertical brings beryl to the form Atomech. §. 271. Topaz has also been accurately determined from its chemical formula given in 78.

167. A more detailed explanation of the formation of snow-crystals we gave in the Scientific American, New York, April 18, 1868, with 7 figures.

168. The relation between physical properties and molecular crystalline constitution has been treated of in Atomechanik, p. 42—44, Contrib. III., p. 43—46, and in Contrib. V. Also, in a paper of 1868, "on the reality of rhombo-tesseral forms," which has not yet been published.

169. The above must be sufficient to show that the problem (152) can be solved, because it *has* been solved in several important cases.

170. In conclusion, we express the hope that, at no distant day, we may be enabled to present the subject of this chapter in a more complete form, as a revised and largely improved edition of the fourth section of *Atomechanics*, constituting a treatise of crystallophysics and crystallochemistry, referred to in the preface.

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